Bk. 2

COMPARTMENTAL
COMPUTATIONS

W. RALL

RECORD

7530-222-3525
FEDERAL SUPPLY SERVICE
(GPO)

2/7/63

Do computations involving sustained and brief inhibitions for $\beta = -0.1$

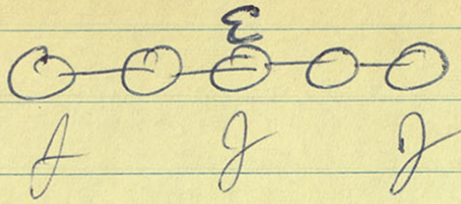
i.e. compartment 11 = 100
compartment 12 = −10

Use ΔT and $\tau\mu_{11} = 1 + \mathcal{E} + J$

$$\tau\mu_{ij} = \left(\frac{1}{\Delta z}\right)^2 = \left(\frac{1}{.04}\right) = 25$$

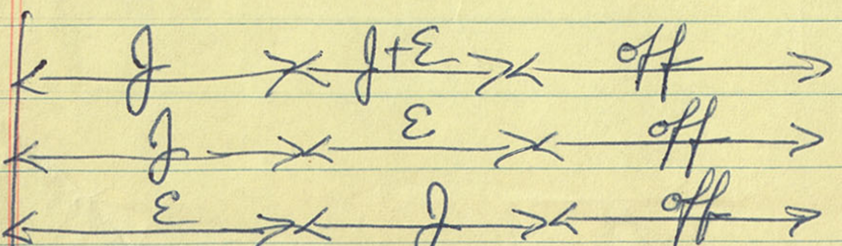
Could use 5 compartments plus two and view results in all five compartments.

Use new data point generation method.



? Spatio temporal patterns

J first can produce some local knocks



and need $\mathcal{E}$ alone control
J alone control

6/3/63

Mones paper with Schoenfeld 1956
p. 1363 Eq. (17)

Suppose $q_i(0) \neq 0$ only for $i=1$
& we watch transient in kth cpt.

$$q_k(t) = \sum_j A_{kj} e^{-\alpha_j t}$$

where $$A_{kj} = \left\{ \left\{ \frac{\Delta_{1k}(p)}{\Delta(p)} q_1(0) \right\} [p+\alpha_j] \right\}_{p=-\alpha_j}$$

This does not treat multiple roots.

Now, for each j, expect that A_{1j} is the same for I.C. in kth.

i.e. $$q_1(t) = \sum_j A_{1j} e^{-\alpha_j t}$$ same α_j

where $$A_{1j} = \left\{ \left\{ \Delta_{k1} \right. \right.$$

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~~Bldg 10, 11N-119~~
Bldg 31, 9A23

Compartmental Computations
Record

Wilfrid Rall

This record begun May 7, 1963, but retrospective to July 1962, based on loose notes from that period.

From May 1963 onwards, this became Computations diary Book 2.

Berman – Weiss
NIH – OMR Computer Program 9B19

revised Feb 1963 to number 9B20

7/17/62

722.001 BIF. TREE
723.001 ADDBR. TREE

Data cards were set up by Marj. Weiss from my outlines & were run as preliminary problems

Assumptions were

$$\Delta Z = 0.2$$
$$\Delta T = 0.1$$
$$\lambda_{oi} = 0.1$$
$$\lambda_{ij} = 0.5$$

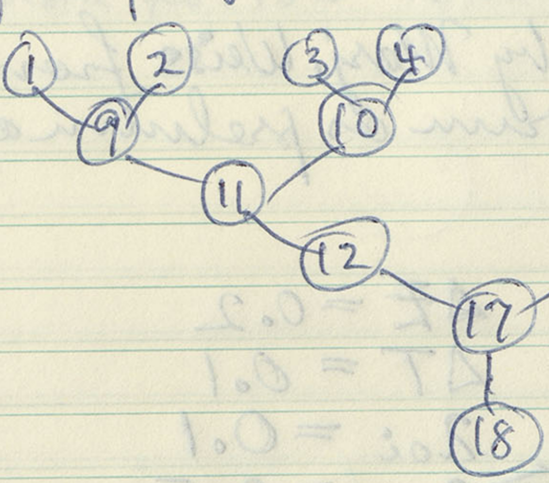
This was a mistake $\frac{\Delta T}{\Delta Z} = \frac{0.1}{0.2} = 0.5$
where it should have been

$$\frac{\Delta T}{(\Delta Z)^2} = \frac{0.1}{0.04} = 2.5$$

$\lambda_{ij} = 0.5$ with $\lambda_{oi} = 0.1$ implies $(\Delta Z)^2 = 0.2$
or $\Delta Z = 0.447$

In these problems, used only initial conditions in compartments 1, 2, 3 & 4. Not perturbations.

Originally had intended 18 compartments as below, but found this was too much for program



722.001 RALL. BIF. TREE

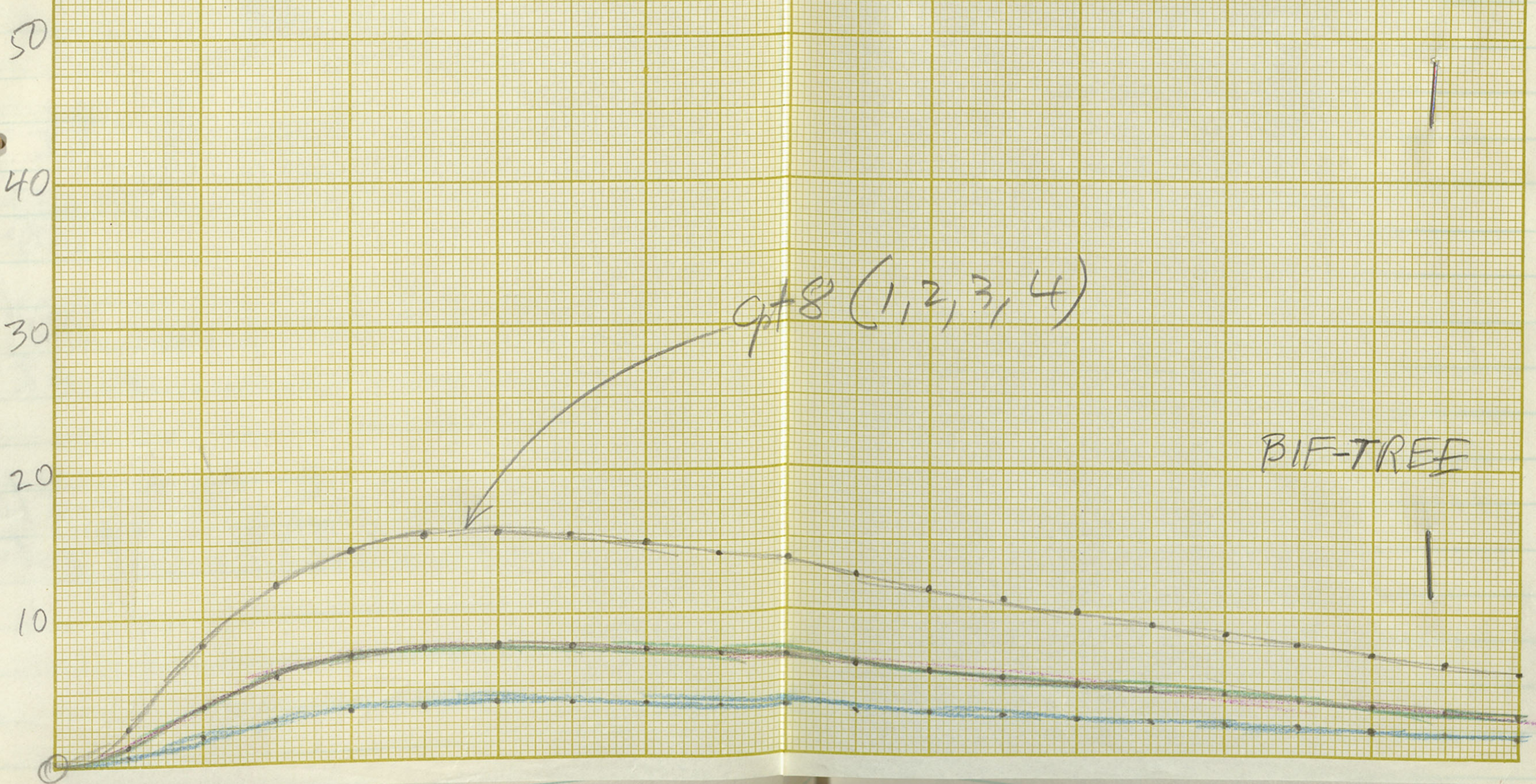
del)

④

Run
7/26/62

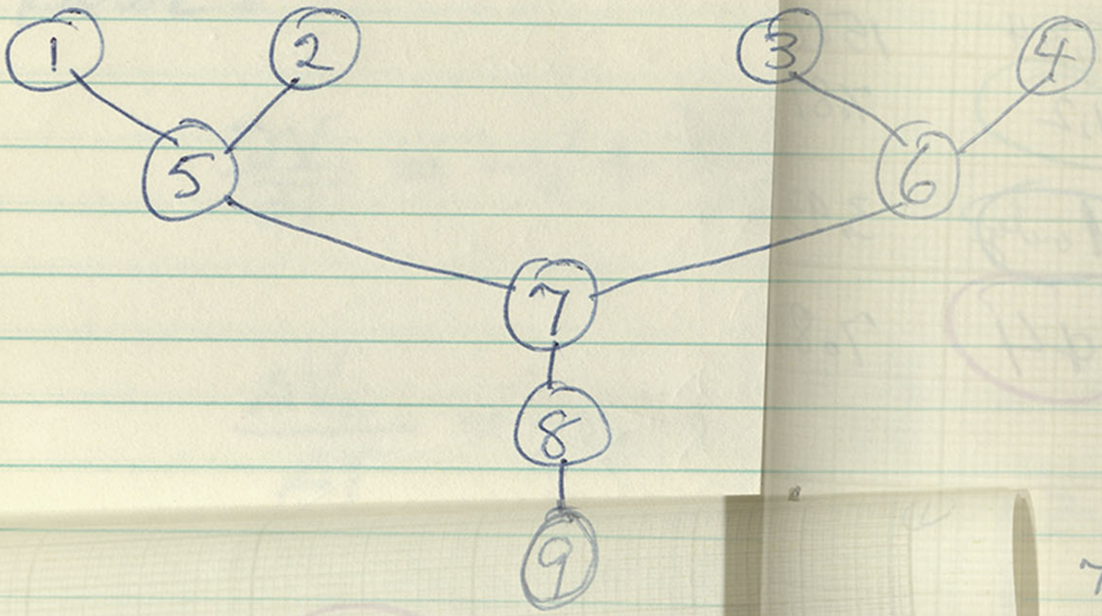
		Peaks	
In 8	1,2,3,4	15.7	at .6
	1,2	7.87	at .6
	1 only	3.93	at .6
	144	7.87	at .6

Same



722.001 RALL. BIF. TREE

(Bifurcating tree model)



Run
7/26/62

These two problems established feasibility.

Correction of λ_{ij} and handling of perturbations came about two months later.

$$\frac{\partial V}{\partial T} = -V + \frac{\partial^2 V}{\partial Z^2}$$

$$\frac{\Delta V_2}{\Delta T} = -V_2 + \left[\frac{\frac{V_3 - V_2}{\Delta Z} - \frac{V_2 - V_1}{\Delta Z}}{\Delta Z}\right]$$

$$= -V_2 - \frac{2V_2}{(\Delta Z)^2} + \frac{V_1 + V_3}{(\Delta Z)^2}$$

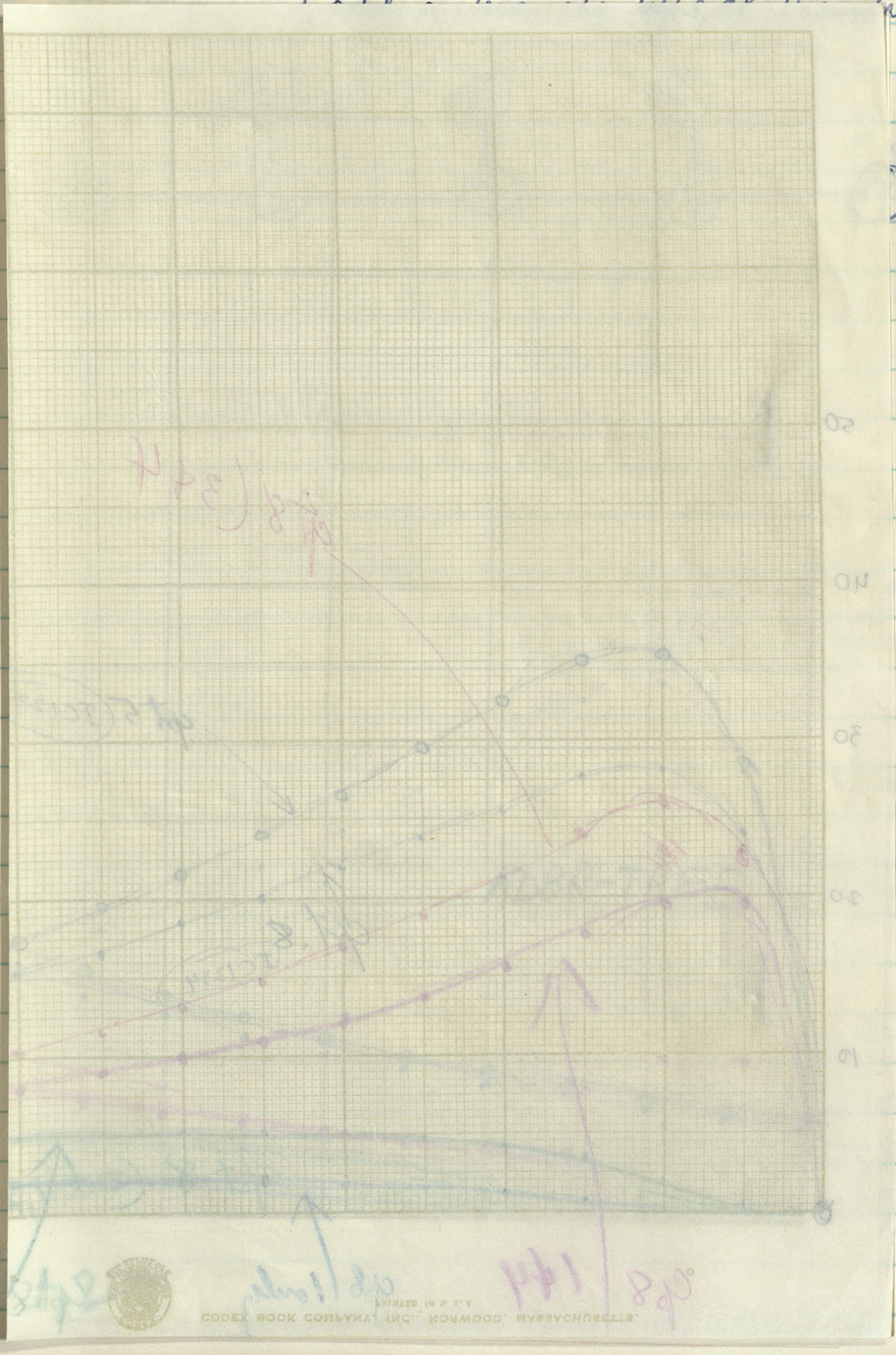
$$\Delta V_2 = -\underbrace{\left\{\underset{\overset{\uparrow}{\lambda_{02}}}{\Delta T} + \frac{2\Delta T}{(\Delta Z)^2}\right\}}_{\lambda_{22}} V_2 + \underset{\overset{\uparrow}{\lambda_{ij}}}{\left(\frac{\Delta T}{(\Delta Z)^2}\right)}\left(V_1 + V_3\right)$$

Moores' program deals with quantity or charge Q not concentration or voltage, V

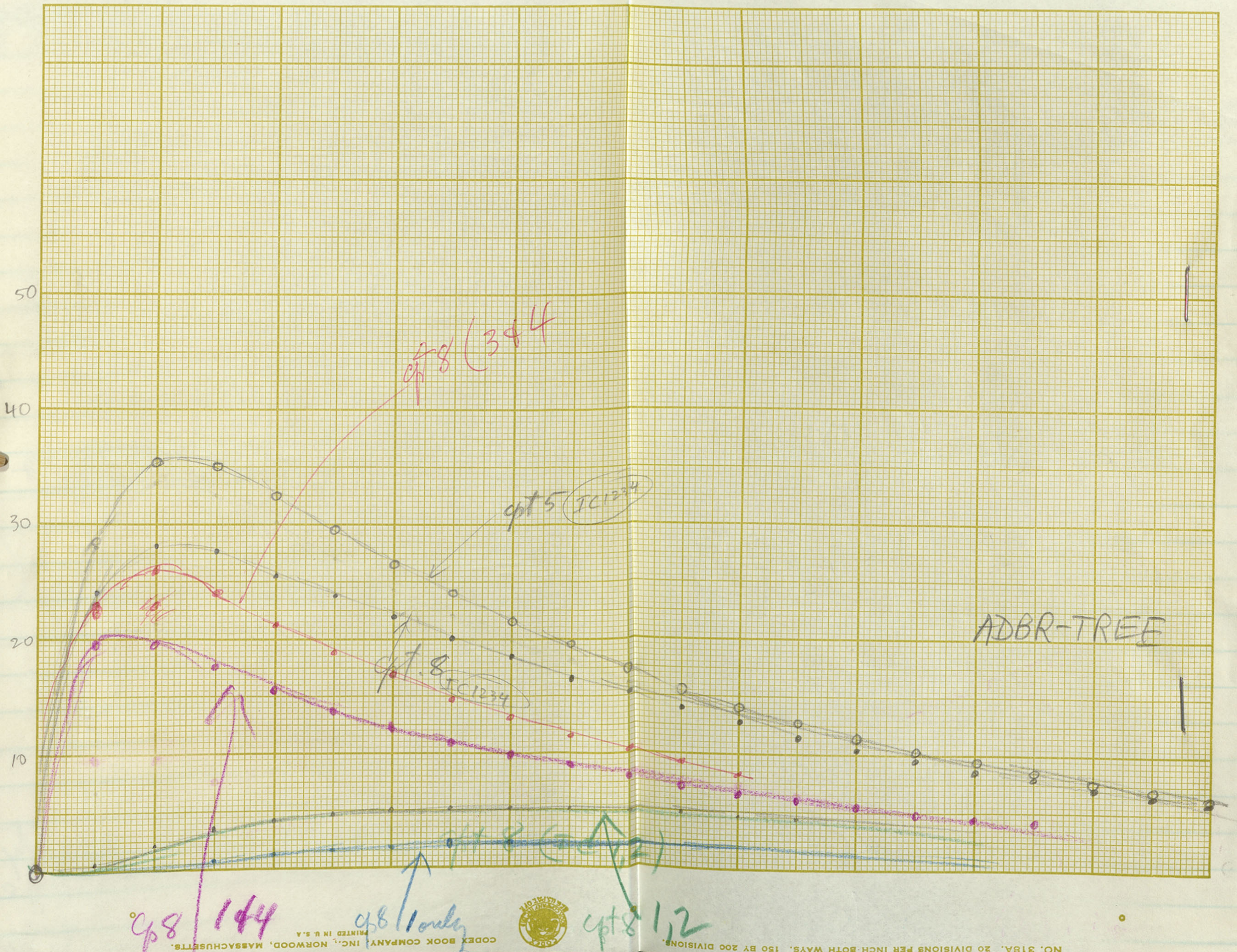
$V \propto Q$ only if all compartments have same capacity

723.001 RAhh. ADDBR. TREE

([illegible] ung)

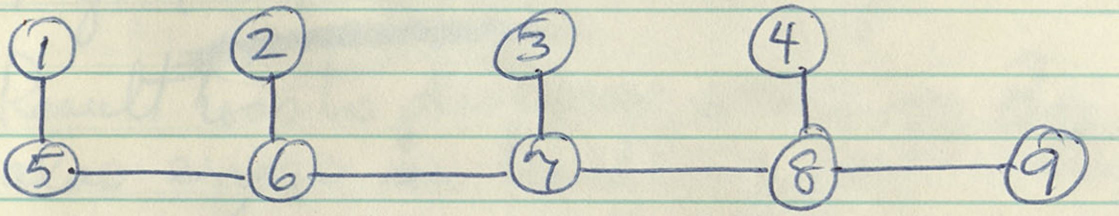


Run
7/24/62

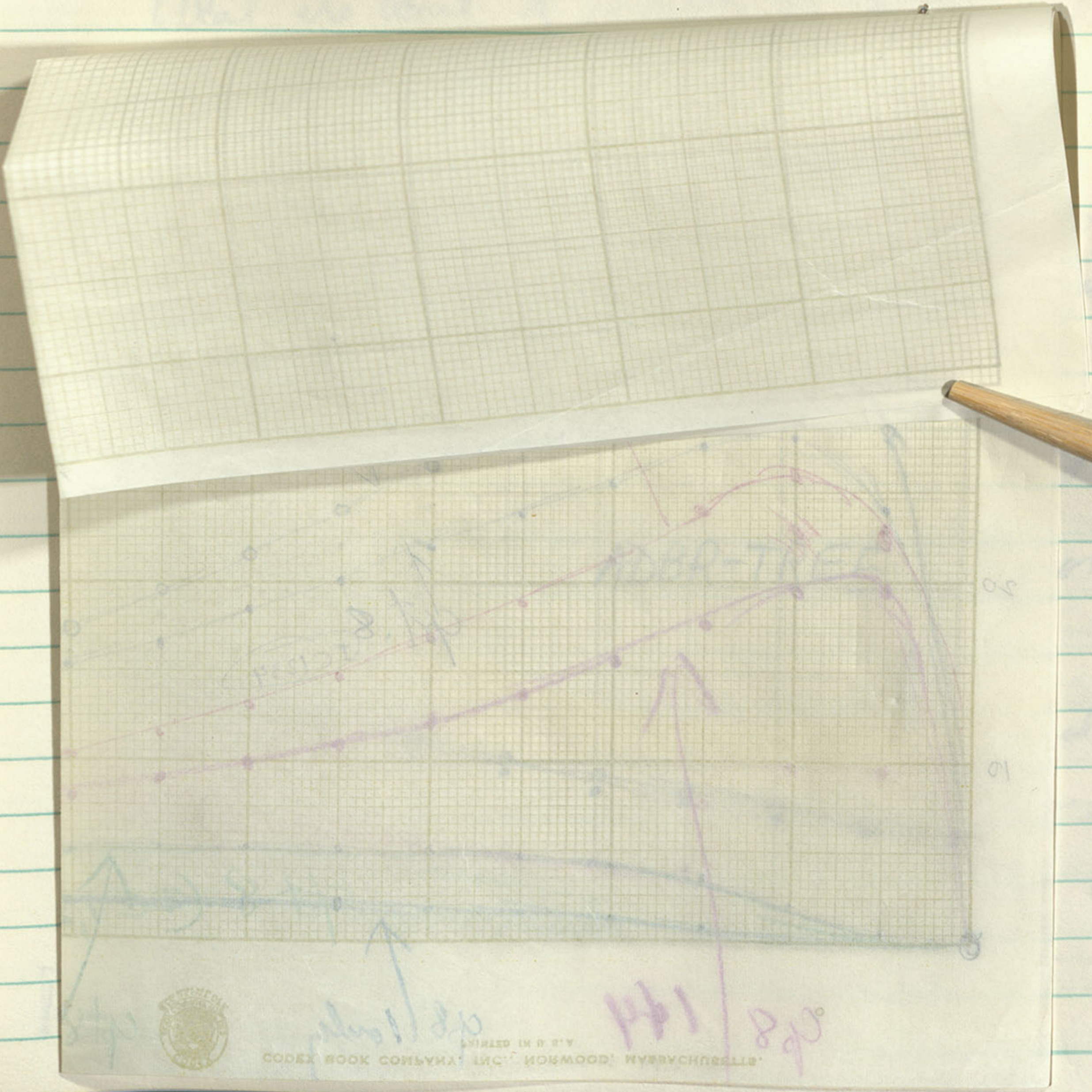

50
40
30
20
10
cpt 8 (3&4
cpt 5 (IC1234)
cpt 1.8 (IC1234)
ADBR-TREE
cpt 8 (1&2)
cp8 1&4
cp8 1 only
cpt 8 1,2

723.001 RAHL.ADDBR.TREE

(add-a-branch type of branching)



Run
7/24/62



9/18/62

730.007 RALL. EQUIV. CYL

Purpose was to test method against Figs 7 & 9 of N.Y. Acad. Paper.

~~730.071 next page~~

Result was to discover error in λ_{ij} & also errors ~~in~~ handling perturbations.

* Source compartment is kept const. by setting up dependence relation such that its out λ is $\overset{\ominus}{\text{sum}}$ of λ into it.

First run was 9/21/62

errors in set-up

need fictitious observed values to set plot

Second run was 9/25/62

errors in time change numbering

* if zero type time change, time restarts from zero

Single page plotting option - max time scaled to 50

double page " " was 111, late changed to 110

For ordinates, should set obs. dummy to 90

Results led to 730.071, next page

Sum of squares in compt. ① cold end was smaller with $\lambda_{ij} = 5.0$

However $\lambda_{ij} = 4.903$ or 4.93

succeeds in reducing sum of squares at hot end without increasing it as much at cold end.

9/26/62

730.071 RALL. EQUIV. CYL

This makes use of data fitting feature of Moore's program to find λ_{ij} which fits the curves of N.Y. Acad. paper.

Oct. 2, 1962 λ_{ij} began at 0.5 ± 0.3; went to 0.8

Oct. 3, 1962 run began with $\lambda_{ij} = 0.8$
range 0.8 to 2.
went all the way to 2.

Oct. 3, 1962 rerun with $\lambda_{ij} = 2$
range from 0.8 to 5
went to $\lambda_{ij} = 4.93$
& got excellent fit.

Oct. 18 rerun began with $\lambda_{ij} = 5.0$; got 4.9036

This proved need for $\lambda_{ij} = \frac{\Delta T}{(\Delta Z)^2}$

for $\Delta T = 0.05$
$\Delta Z = 0.1$

$$\boxed{\frac{\Delta T}{(\Delta Z)^2} = \frac{.05}{.01} = 5}$$

Active $\lambda_{oi} = 0.15$
Passive $\lambda_{oi} = 0.05$

λ_{oj} passive = .05
λ_{oj} active = .10
λ_{ij} = 1.25   for $\Delta Z = 0.2$
$\Delta T = 0.05$

I.C. air source cpt was 100.

Obs. Max was 45.

Max time was 50. with option 4

10/30/62

730.102
.103

Equiv. Cyl.

Here attempted spatiotemporal sequence, but SNAFU

Parameter changes did not work correctly because I did not know that after a time change, as long as one new param. is specified, all not specified revert to the original values, not the previous values.

Also source compartment was not successfully held const, because had not yet used dependence relation for $\lambda_{osource}$.

Solution is that $\lambda_{osource} = \sum_j \lambda_{sj\,in\,source}$

And zero time values of parameters should all be passive values

Thus all non-passive values made explicit.

* Return to passive always requires one explicit card to avoid continuation with previous values.

Studied Matrix
9 compartments plus ⑩ for E source
⑪ for J source

Diagonal elements

at terminals of tree, $\lambda_{ii} = \frac{\Delta T}{(\Delta Z)^2} + \Delta T + \lambda_{i,10} + \lambda_{i,11}$

For elements in line, $\lambda_{ii} = 2\left(\frac{\Delta T}{(\Delta Z)^2}\right) + \Delta T + \lambda_{i,10} + \lambda_{i,11}$

at branch points, $\lambda_{ii} = 3\left(\frac{\Delta T}{(\Delta Z)^2}\right) + \Delta T + \lambda_{i,10} + \lambda_{i,11}$

This is with all cpts of same size

If $\Sigma d^{3/2} = \text{const}$ (i.e. $K=0$)
Branch points gone same as elements in line.
Then bear in mind that Mones prog. is for Q

Each branching yields a smaller compartment which means smaller I.C. and smaller $\lambda_{i,\text{source}}$. Also λ_{ij} where i is smaller compartment must be reduced proportionately.

used this later, successfully in 722.500 series

10/31/62

722.011 BIF. TREE

$\Delta T = 0.05$

$\Delta Z = 0.2$

$\lambda_{ij} = \frac{.05}{.04} = 1.25$

$\lambda_{o\,passive} = 0.05$

$\lambda_{o\,active} = 0.15$

still did not have dependence relation for source

ie. as with 730.102 learned this here ↑

& also parameter changes.

Negative plotted values were the **clue** that ~~resolved this~~ led to solution of trouble. The source compartment went negative in one of these.

11/2/62

This day initiated following regime

① Initial λ set-up all with passive values

② $\lambda_{0,\text{source}} = -\sum_j \lambda_{j\,\text{source}}$

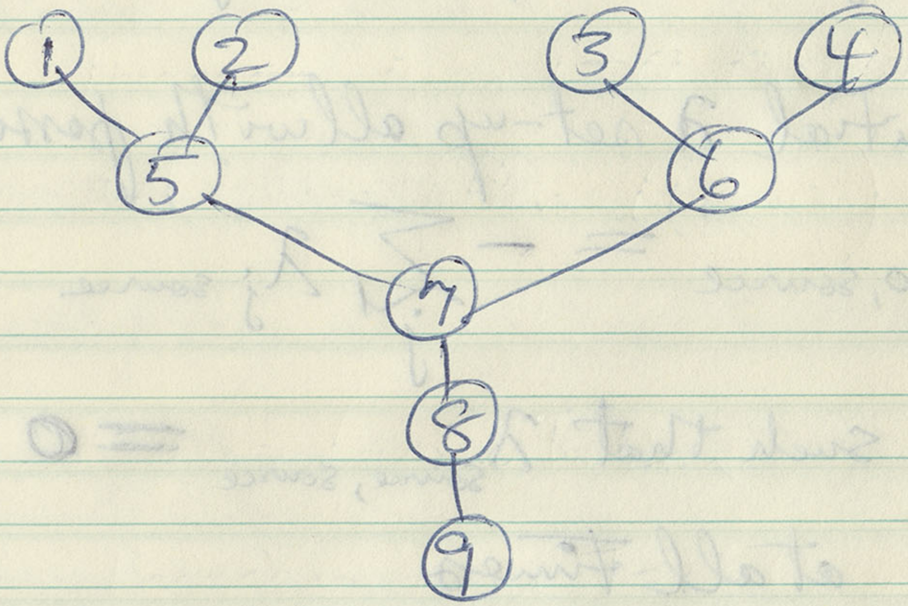
such that $\lambda_{\text{source, source}} = 0$

at all times

③ all parameter changes ~~must~~ now be stated as explicit perturbations.

④ ~~[illegible]~~ return to passive set requires one explicit passive card.
(This was learned only 11/8/62)

⑤ ~~For~~ every restart zero type time change it is necessary to recharge the source initial condition



Computed time course in ⑧

$\lambda_{0\,passive} = 0.05$
$\lambda_{0\,active} = 0.15$
$\lambda_{active,\,source} = 0.10$

$\lambda_{ij} = 1.25$ for $\Delta T = 0.05$
$(\Delta Z)^2 = 0.04$
$\Delta Z = 0.2$

Began New Bif. Tree Series 11/2/62

722.200 BIF. TREE Series

11/8/62 tests failed to return to passive parameters because did not use passive card

Also, used Obs. value 45.
Plot option 4
Last time value 25.

This plotted with correct spacing except that one should give an explicit zero time value after each zero type time change control card.

11/9/62 tests worked because of passive card

also doubled scale of plotting by setting

Obs. value = 22.5
Need because → Plot option 3
Last time value = 27.5

Single curve overran single page.

because (4)(27.5) = 110
Spaced 4 per point.

Observe in compartment 8

A is first perturbation

This is on from T=0 thru T=5

and is then followed (usually passive) to T=20

B is second perturbation

This is on from T=0 thru T=5

and is then followed (usually passive) to T=20

C is I.C. for final transient

followed to T=27.5

Note: $E_j = E_r$ throughout

		A	B	C
722.201	11/9/62	Ɛ=2 in 1,2,3,4	Ɛ=2 in 1	I.C. in 1,2,3,4
722.202	11/9/62	Ɛ=2 in 1&2	Ɛ=2 in 1&4	I.C. in 1&2
722.203	11/13/62	Ɛ=2 in 1&2 J=2 in 3&4 (brief)	goof	I.C. in 1
722.204	11/13/62	I.C. in 1&2 J=2 in 3&4 (brief)	I.C. in 1&2 J=2 in 5&7 (brief)	I.C. in 5&6
722.205	11/15/62	Ɛ=2 in 1 J=2 in 2 (sustained)	Ɛ=2 in 1 J=2 in 4 (sustained)	I.C. 1&2 J=2 in 1&2
722.206	11/15/62	Ɛ=2 in 1 J=2 in 5 (brief)	Ɛ=2 in 1 J=2 in 7 (brief)	I.C. in 1 J=2 in 2
722.207 A	11/15/62	goof	goof	I.C. in 1 J=2 in 1
722.207 B	11/16/62	Ɛ=8 in 1 passive	Ɛ=2 in 1 J=2 in 1 (sustained)	I.C. in 1 J=2 in 4

		A	B	C
722.208	11/16/62	$\varepsilon=2$ in 1 $g=2$ in 5 (brief)	$\varepsilon=2$ in 1 $g=2$ in 7 (brief)	I.C. in 1 $g=2$ in 5
722.209	11/16/62	$\varepsilon=2$ in 1 $g=2$ in 2 (brief)	$\varepsilon=2$ in 1 $g=2$ in 4 (brief)	I.C. in 1 $g=2$ in 7
722.210	11/20/62	$\varepsilon=2$ in 1 $g=2$ in 5 (sustained)	$\varepsilon=2$ in 1 $g=2$ in 7 (sustained)	I.C. in 1 $g=2$ in 6
722.211	11/20/62	$\varepsilon=2$ in 1 $g=2$ in 8 (brief)	$\varepsilon=2$ in 1 $g=2$ in 8 (sustained)	I.C. in 1 $g=2$ in 8
722.212	11/20/62	$\varepsilon=4$ in 1	$\varepsilon=2$ in 1 $g=2$ in 1 (brief)	I.C. in 1 $g=2$ in 5+7

7220.2

11/21/62

Linearity of Peak in 8 for perturbations ε superposing

		factor
ε = 2 in ① gives peak	= 3.40385	
ε = 4 " " "	= 6.23517	1.83
ε = 8 " " "	= 10.6348	3.12
ε = 2 in ① & ②	6.60179	1.94
ε = 2 in ① & ④	6.77025	1.99
ε = 2 in ①, ②, ③ & ④	13.0574	3.84

for brief substitution J, simultaneous with E

Control	3.40385
1	3.11758
5	3.25186
2	3.3009
7	3.3266
8	3.34839
④	3.38512

Note: $E_j = E_2$ throughout

722.2

11/21/62

Sustained Inhibition of Peak at ⑧ for different Sites of Inhibition

Site	$\Sigma = 2$ in!		I.C. in 1
Control	3.40385		3.83
1	3.02447	first	3.40153
8	3.09329	second	3.50277
5	3.14478	third	3.5566
7	3.18729	fourth	3.6056
2	3.23036	fifth	3.658
6			3.76
3 or 4	3.36073		3.796

Remarkable that J sustained in 1 is more effective than in 8. Perhaps because persone $\lambda_{11} < \lambda_{88}$

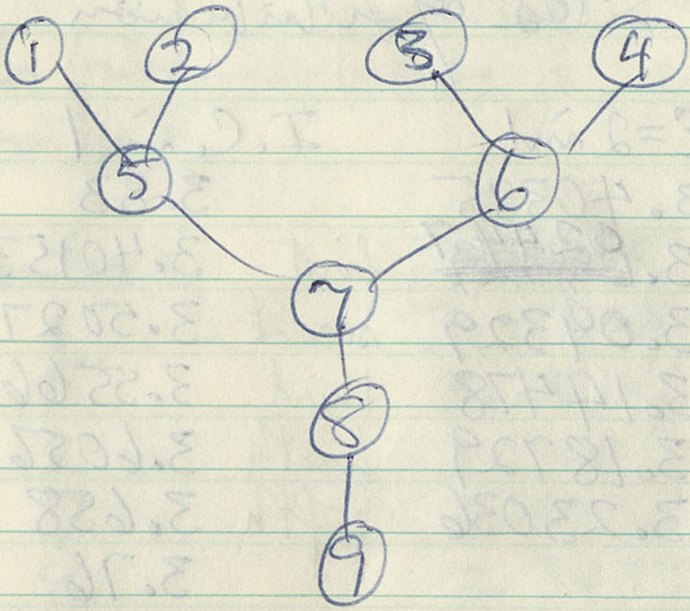
Also that 5 is more effective than 7.

see 722.239 7/1/63

These pairs get reversed for $\Sigma d^{3/2} \equiv$ Const. in 722.500 series.

only when J was not adjusted for compt. size.

① better than ⑧
and ⑤ better than ⑦
and ⑧ better than ⑦
} preserved in 722.530 series May, 1963



all $\lambda_{ij} = 1.25$

except for $\lambda_{6,7} = \lambda_{57} = \lambda_{46} = \lambda_{36} = \lambda_{25} = \lambda_{15} = 0.625$

also I.C. were 12.5 here
instead of 50 in 722.200 series

Amplitudes came out roughly half
those in 722.200 series

ie total inhib conductance in ① was only
1/4 that in ⑦ or ⑧
in ⑤ it was 1/2 that in ⑦ or ⑧

See 722.530 series in May 1963

11/7-29/62

722.500 Series $\left(\begin{array}{l} K=0 \\ \Sigma d^{3/2} = \text{const} \end{array} \right)$

		A	B	C
722.501	11/13/62	$\varepsilon=2$ in 1, 2, 3, 4	$\varepsilon=2$ in 1 only 1.568	I.C. in 1, 2, 3, 4 4|6.987 1.747
722.502	11/29/62	$\varepsilon=2$ in 1 $j=2$ in 1 (sustained) 1.426	$\varepsilon=2$ in 1 $j=2$ in 8 sustained 1.405	I.C. in 1 $j=2$ in 8 1.580
722.503	11/29/62	$\varepsilon=2$ in 1 $j=2$ in 5 (sustained) 1.439	$\varepsilon=2$ in 1 $j=2$ in 7 (sustained) 1.418	I.C. in 1 $j=2$ in 1 1.584

1.568 is control

Note that ⑤ is less effective than ①

Probably ought to collect outflow

plan to do this 5/8/63

Here $\boxed{G_j \Delta A}$ was not the same in the different positions

722.601 did not work but because λ_{ij} were set equal to unequal μ_{ij}; leading to incorrect λ_{ii} etc.

Begin $\boxed{730.900 \text{ series}}$ 11/2/62

Equivalent Cylinder – Ten Compartments
Spatio – Temporal pattern

11/8/62 runs were erroneous because did not get correct passive decay.

730.901 thru 730.910B

See table next two pages

I Used $\Delta t = 1$ really corresp to $.05\,\tau$

$\therefore\ \lambda_{oi} = 0.05$

$\lambda_{ij} = 1.25$ corresp to $\Delta Z = 0.2$

i.e. $\frac{.05}{(.2)^2} = 1.25$

Δt for perturbations was 5 steps. or $0.25\,\tau$

Compartment 11 was source comp., set at 100.

TC perturbations made explicit rel. to passive original values.

Results computed in compartments ① and ⑩

Date	Prob. No.	Δt_1	Δt_2
11/9/62	730.901	$\varepsilon=1$ in 2+3	$\varepsilon=1$ in 4+5
"	730.902	"	$J=1$ "
11/13/62	.903	δ pulse ε "	δ pulse ε "
11/9/62	.904	δ pulse ε "	passive "
11/13/62	.905	$\varepsilon=1$ in 2+3	$\varepsilon=1$ in 4+5
11/15/62	.906	$\varepsilon=1$ "	$J=1$ "
11/15/62	.907	$\varepsilon=1$	$\varepsilon=1$
11/15/62	.908	$\varepsilon=1$	passive
11/15/62	.909	$\varepsilon=1$ in 2+3	
11/15/62	.910	$\varepsilon=1$ in 4+5	
2/8/63	.911	$\varepsilon=0.25$ in 2–9	
11/19/62	730.906B	$\varepsilon=1$ in 5+6 for Δt_1	
11/19/62	.907B	$\varepsilon=1$ in 4+5 for Δt_1	
11/19/62	.908B	$\varepsilon=1$ in 6+7 for Δt_1	
11/19/62	.909B	$\varepsilon=1$ in 2+3 for Δt_1	
11/19/62	.910B	$\varepsilon=1$ in 4+5 for Δt_1	

Δt_3	Δt_4	final time	Used for Ojai ↓
$\varepsilon=1$ in 6+7	$\varepsilon=1$ in 8+9	passive	*
"	$J=1$ "	passive	
δ pulse ε "	δ pulse ε	passive	
δ pulse ε "	passive	passive	
$\varepsilon=1$ in 6+7	passive	good for a figure to peal passive	
$\varepsilon=1$	passive	passive	
passive for peal	passive	passive	
$\varepsilon=1$	passive	passive	

*

*

for all four Δt [smeared control] *

with $J=1$ in 1, 2, 3, 4 throughout
and $\varepsilon=1$ in 2+3 for Δt_2, then passive
passive Δt_2, then $\varepsilon=1$ in 2+3 for Δt_3, then passive
with $J=1$ in 8+9 throughout
with $J=2$ in 1, 2+3 throughout

This was first use of data point generation system

200. Δt N

11/15/62

11/16/62

11/20/62

11/29/62

12/1/62

Begin $\boxed{730.920}$ Series 11/15/62

Ten Compartmental Equiv. Cylinder
$\varepsilon = 1$ in 5&6
Different locations of j

I.C. in Source Cpt

730.921 $\varepsilon = 1$ in 5&6 control 100

730.922 $\varepsilon = 1$ in 5&6 " 500
and $j = 1$ in 3&4 throughout 500
$\varepsilon = 1$ in 5&6
$E_j = 0$

730.923 $\varepsilon = 1$ in 5,6, $j = 1$ in 5&6 500
brief , sustained
$\varepsilon = 1$ in 5,6, $j = 1$ in 1&2

730.924 $\varepsilon = 1$ in 5&6, brief 500
followed by $j = 10$ in 5,6
$\varepsilon = 1$ in 5&6, brief 500
followed by $j = 10$ in 1,2

730.925 $\varepsilon = 1$ in 5&6 brief 500
$j = 10$ in 5&6 throughout
$\varepsilon = 1$ in 5&6 brief 500
$j = 10$ in 1&2 throughout

730.800 Series 11/20/62

Ten Compartmental Equiv. Cyl.

50:50 ε + J Splits

Source Compt set at 100

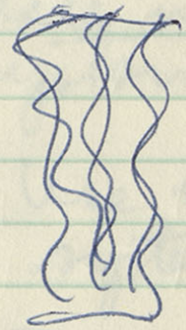
11/20/62 730.801 $\varepsilon = 1$ in 1, 2, 3, 4, 5 brief
$J = 1$ in 1, 2, 3, 4, 5 Sustained

11/20/62 730.802 $\varepsilon = 1$ in 1, 2, 3, 4, 5 brief
$J = 1$ in 6, 7, 8, 9, 10 sust.

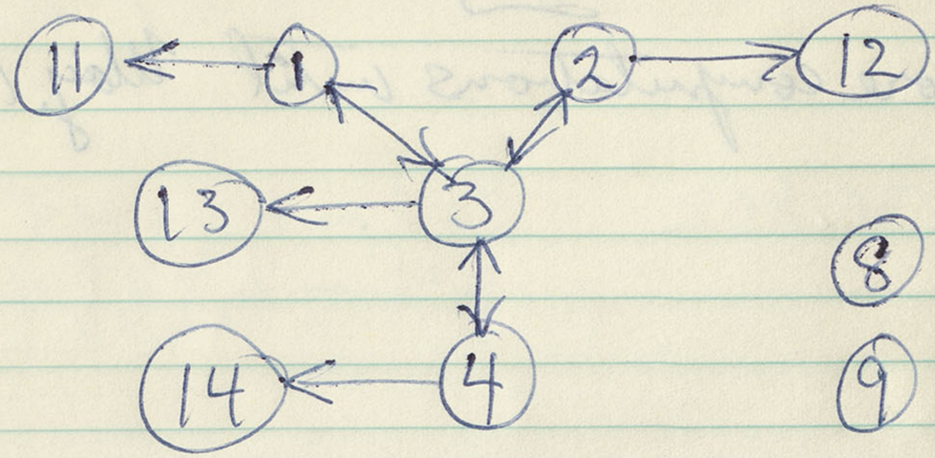
Dec 1962

Break for Trip to L.A.
& Seattle
to present material

Manuscript written in Feb & Mar 1963



No more computations until May 1963



⑧ Ɛ

⑨ g

May 1963

Plan to begin new series 731.000
and 731.100

Purpose to elucidate inhibitory location in branching system.

Approach: ① Use minimal branching system

② Collect "out" leakage

③ Do first for inst. pulse, Then for square pulse.

Improved Methods

① Use data point generating system

② make all other λ_{ij} dependent upon first. This permits easy shift of ΔZ

③ use $\lambda_{ij} = \tau \mu_{ij} \frac{c_i}{c_j} = \left(\frac{1}{\Delta Z}\right)^2 \frac{c_i}{c_j}$

and express Δt steps as $\Delta t/\tau$

* ④ Make λ_{oi} explicitly dependent $= 1 + \varepsilon + J$
$= 1 + \lambda_{i\varepsilon} + \lambda_{iJ}$

or collected version

only for equal cpts.

5/8/63

731.001

Begin with I.C. = 90. in ①

$\Delta Z = 0.5$ giving $\lambda_{ij} = \tau\mu_{ij}\frac{c_i}{c_j} = 4.$

Resting $\lambda_{11,1} = \lambda_{12,2} = \lambda_{13,3} = \lambda_{14,4} = 1.$

Perturbations referred to resting values
for $E_j = E_r$, simply express

e.g. $\lambda_{11,1} = 1.*(\text{resting value}) + J$

$\Delta T = 0.02$
$NT = 25$

used $J = 5$
in first runs.

731.001.0	I.C. in ①,	Control with no J	
731.001.1	"	with J=5 in	①
731.001.2	"	"	②
731.001.3	"	"	③
731.001.4	"	"	④

Maj. Weiss took to NBS for punching
output obtained 5/16/63

731.001.0 Thrm 1.4 5/16/63

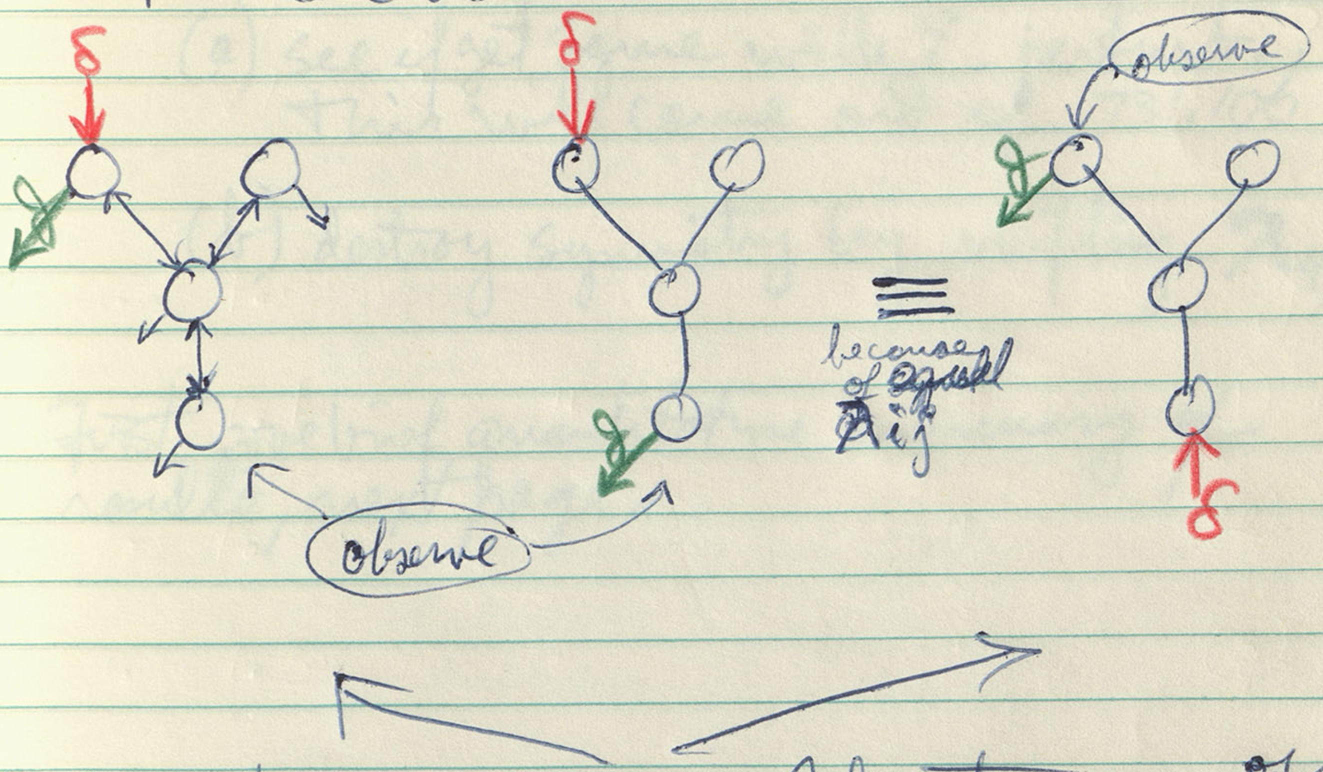
Successful run

Most striking result due to symmetry.

Transient in compartment ④ is identical for $\begin{cases} J = 5 \text{ in } ① \\ J = 5 \text{ in } ④ \end{cases}$

all through transients in the other compartments differ in these two cases

This can be understood as



These two involve same J location, with I.C. (δ) interchanged with observation compartment. Theorem of which Zim has a math. proof. Mones relates principle to Thevenin

5/17/63

In otherwords, for this case of perfect symmetry, J located at I.C

& J located at recording pt.

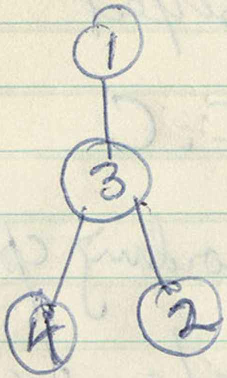
are equally effective, which explains paradoxical results obtained earlier with trees.

Two paths of pursuit

(a) see if get same with E perturb.
this will come out of 731.100 series

(b) destroy symmetry by shifting $\lambda_{4,3}$

First give brief quantitative summary of results, next page.


1
3
4
2

731.001 5/17/63

	peak in ③	peak in ④	peak in ②
Control	17.74 at 0.18	11.20 at 0.48	same as 4
J=5 in ①	12.47 at 0.10	6.164 at 0.32	same as 4
J=5 in ③	13.37 at 0.12	7.34 at 0.36	same as 4
J=5 in ④	17.49 at 0.16	6.164 at 0.32	10.53

note that seen from ④ J in 1&4 same & better than J in 3

seen from ③ J in 1 is better than J in 3

At time 0.32 of peak in ④, find

	in ①		③		④	②
~~Control~~ J in ① →	7.235	←	7.530	→	6.164	6.164
J in ③	25.44	→	9.97	→	7.27	7.27
J in ④	28.20	→	15.24	→	6.164	10.03

for J in ① value in ① drops below value in ③ between T = 0.30 & 0.32 and remains below from then on

value in ③ drops below value in ④ or (2) between T = 0.42 & 0.44 and stays below.

$$\begin{array}{ccccc} c_i \mu_{ij} & = & & = & c_j \lambda_{ij} \\ & & g_{ij} = g_{ji} & & \\ c_j \mu_{ji} & = & & = & c_i \lambda_{ji} \end{array}$$

$$\lambda_{ij} = \frac{g_{ij}}{c_j} = \frac{c_i}{c_j} \mu_{ij} = \mu_{ji}$$

$$\lambda_{ji} = \frac{g_{ij}}{c_i} = \frac{c_j}{c_i} \mu_{ji} = \mu_{ij}$$

Suppose compartment ④ has both its capacity and its g_{34} changed in some ratio

Then λ_{34} remains unchanged

but λ_{43} is changed by factor

③ When ④ is changed, $g = V/C$, no longer gives V. Need Kappa to make comparable.

731.002 Corrected next page 5/20/63

731.002.1 I.C. in ①, J = 5 in ①, $\lambda_{4,3} = 3.6$

.2 " " $\lambda_{4,3} = 4.4$

.3 " J = 5 in ④, $\lambda_{4,3} = 3.6$

.4 " " $\lambda_{4,3} = 4.4$

.9 no inhibition, but $\lambda_{ij} = 25$ for $\Delta Z = 0.2$

		peak in 4
J in ①	$\lambda_{4,3} = 3.6$	5.6705
	4.0	6.164
	4.4	6.638 at T = 0.30
J in ④	$\lambda_{4,3} = 3.6$	5.69
	4.0	6.164
	4.4	6.617 at T = 0.30

Fits intuitive expectations, but there are ~~two~~ three defects.

① ④ was changed without compensatory change in ② to keep total size of system constant

② Compensatory changes in J should also be made to keep total C_j const.

*Successful juggling of compartment sizes.

Results

Peak Q_4	Peak $K_4 * Q_4$		Peak Q_3
5.548	6.164		12.466
6.781	6.164		12.466
5.310	5.90	down 0.264	17.493
7.044	6.403	up 0.24	17.487
2.186	4.372 at T=0.26	-	17.516

i.e larger J in smaller compt. is more effective

5/20/63

Set up 731.011 et seq. to provide that

ⓐ $\lambda_{43} + \lambda_{23} = 2\lambda_{13}$

do this by setting λ_{43} factor $= 0.9$ or 1.1
λ_{23} " $= 1.1$ or 0.9

ⓑ when $\lambda_{4,3} = 0.9$, J in ④ should be 5.56
$K = 1.111$
~~$\lambda_{4,9}$ 6.~~
$\lambda_{14,4} = 6.56$

ⓒ Kappa adjusted to give $V_i \doteq K_i Q_i$

when $\lambda_{4,3} = 1.1$, $\lambda_{4,4} = 5.54$
$K = 0.9091$

K_2Q_2		factor $\lambda_{4,3}$	factor λ_{23}	
6.164	731.011	0.9	1.1	$\lambda_{11,1} = 6.$
6.164	731.012	1.1	0.9	"
10.544	731.013	0.9	1.1	$\lambda_{14,4} = 6.565$
10.509	731.014	1.1	0.9	$\lambda_{4,4} = 5.545$
10.66	731.015	0.5	1.5	$\lambda_{44,4} = 11.$
		$K_4 = 2.$	$K_2 = 0.333$	

for $\lambda_{43} = 0.9$, need $K_4 = 1.111$, $K_2 = .9091$

for $\lambda_{43} = 1.1$, need $K_4 = .9091$, $K_2 = 1.111$

$$\lambda_{ii} = \lambda_{oi} + \sum_{j\neq i} \lambda_{ji}$$

$$\lambda_{oi} = 1 + \varepsilon_i + g_i$$

But $\varepsilon_i \propto \lambda_{i,\text{source}}$
$g_i \propto \lambda_{i,\text{sink}}$ } Safe only when all compartments are equal.

e.g. Suppose ⓘ is made half normal size

Then, if normally, $\lambda_{i,\text{source}} = \varepsilon_i$

now $\lambda_{i,\text{source}} = \frac{1}{2}\varepsilon_i$

dependence relation

$$\therefore \lambda_{oi} = 1 + (2.)\lambda_{i,\text{source}} + (2.)\lambda_{i,\text{sink}}$$

and this is true whether or not we decide to double ε_i to keep $\varepsilon_i \cdot \Delta A_i$ constant.

Also, need $K_i = 2.$ for this case

(See 6/26/63) tabbed page.

Summary 731.001 } Series
.002
.011 – .015

all these series were with I.C. in ①
(not E pulse)
also $\beta = 0$

A. With four cpts. of equal size, J in ① & J in ④ are precisely equally effective as seen in ④.

B. This symmetry would be destroyed by replacing I.C. with E pulse, because of source cpt. & pulse.
Predict J less effective when super on E because of non linearity.
confirmed by 731.111 and 731.114

C. This symmetry would be destroyed by making
NO $\beta \neq 0$, ie. $E_j \neq E_2$, because then need sink compartment. Symmetry still O.K., it seems.
Better try this. Confirmed by 731.204 and 731.205

D. Reason why J in ③ is less effective may be that resting $\lambda_{33} = 13$ compared with $\lambda_{11} = \lambda_{22} = \lambda_{44} = 5$. Thus $\Delta\lambda_{0i}$ of 5 is smaller proportion in ③ than in ① or ④. In other words, there is a markedly different effect upon the eigenvalues. However, J in ② ~~gives~~ must give same eigenvalues & yet gives very different peak.
See 731.301

Might pay to check this by making $\lambda_{13} = \lambda_{23} = \lambda_{43} = 4$
$\lambda_{31} = \lambda_{32} = \lambda_{34} = 12$

But this also makes ① ② ④ one third the size of ③ and if J value is same, $J\Delta A$ will be three times as great in ③.

E. When compartment ④ was made smaller & ② compensatorilly larger.

This had no effect for J in ①, provided that correct Kappa was used for ④.

For J in ④, when J was increased to make $J\Delta A$ constant, the effect of J in smaller compartment was greater inhibition than for the normal size cpt.

Conversely; for ④ larger than normal & J correspondingly smaller, the inhibition was less effective.

$\beta = -0.1$

Peak in ①	Peak in ③	Peak in ④
49.45	15.81	10.30
31.24	9.64	5.26
49.06	13.68	-0.08
47.6	7.62	4.05
49.26	14.66	0.3637

731.100 Series run 5/24/63

Source Cpt. ⑧ set at 100.
Sink Cpt. ⑨ set at −10.

also, set $\lambda_{11,1} = 1 + \lambda_{1,8} + \lambda_{1,9}$

which is O.K. as long as cpts are of equal size

otherwise, need to use factors to correct for
$\lambda_{1,8} \neq \varepsilon_1$ and $\lambda_{1,9} \neq J_1$

731.101 Control: $\varepsilon = 5$ in ① for $\Delta T = 0.25$
no inhibition

731.105 $J = 5$ in ① sustained with $\beta = -0.1$
cpt ① went negative for $T > 0.5$

731.104 $J = 5$ in ④ sustained with $\beta = -0.1$
cpt. ④ never got positive

731.103 $J = 5$ in ③ sustained with $\beta = -0.1$

731.102 goofed value of $J = 2.5$ in ④
made cpt. ④ half normal size
cp ② 1.5 × normal size

Should redo with $\beta = 0$ & $\beta = +0.1$

Peaks in ①	③	④
34.71	10.9	6.163
48.71	11.3	6.68
49.42	15.32	5.55
38.18 below control	12.16 below control	7.165 below control
49.77 slightly up above control	17.09 above control	11.22 above control
49.79	14.99	9.54

5/30/63

Set up 731.111 — 731.116

All have E pulse in ①: All Cpts. equal
All Kappas removed

731.111 J = 5 in ① with $\beta = 0$

731.113 J = 5 in ③ with $\beta = 0$

731.114 J = 5 in ④ with $\beta = 0$

731.115 J = 5 in ① with $\beta = +0.1$

731.116 J = 5 in ④ with $\beta = +0.1$

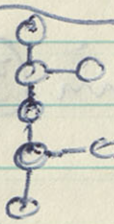
later (June 21) 731.117 J = 5 in ③ with $\beta = +0.1$

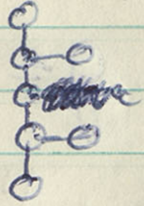
These two results confirm the prediction that J in ① is less effective than J in ④ when observed in ④ with E pulse in ①, ($\beta = 0$) although for I.C. in ①, these two J locations are equally effective when observed in ④.

As seen from ③, J in ① better than J in ③ as was true also for I.C. in ①

This is an incomplete effort to examine the effect that $\lambda_{33} < \lambda_{11}$ ~~=~~ $\lambda_{22} = \lambda_{44}$ when all compartments are equal.

a better method would be





Here middle one has smaller λ_{ii} than its immediate neighbors.

see two pages farther on

Peak in ③	Peak in ④
28.45 at T=0.08	7.269 at T=0.2
28.125 at T=0.08	6.875 at T=0.18
37.1 at T=0.12	7.269 at T=0.2
33.54 at T=.10	8.886 at T=0.22

Order as expected →

5/31/63

Set up 731.031 – 731.035 and 731.201

Here restore $\lambda_{4,3} = \lambda_{2,3} = \lambda_{1,3} = 4.$

and make $\lambda_{3,1} = \lambda_{3,2} = \lambda_{3,4} = \textcircled{3.} * \lambda_{1,3}$
$= 12.$

This should make $\lambda_{11} = \lambda_{22} = \lambda_{44} = 13. = \lambda_{33}$

Not using Kappas.

All have I.C. in ①

731.031 $J = 6$ in ①

731.033 $J = 6$ in ③

731.034 $J = 6$ in ④

731.035 $J = 2$ in ③

↑ to compensate for compartment ③ being three times as large as ①, ② & ④

Predict that transient in ④ will be most inhibited by $J = 6$ in ③
equally by $J = 6$ in ① or ④

σ worked, but did not get st.st. values

6/4/63 Talked with Mary

St. St. part of program ignores initial conditions.

But, if want st. st. values in all cpts, need to specific inflow

In this case, cpt. 4 would have inflow = -50.

ie. (5)(-10.)

Plan to use ⑥ as summer for ①
⑦ as summer for ④

adjust $\sigma_{6,9}$ to give missing st.st. ① from ⑨
" $\sigma_{7,9}$ " ④

at first use -.5 for these sigmas

for 731.202 inhibit ④ goofed
731.203 inhibit ① O.K., got necessary st.st.

204 inhibit ④ rel. to initial st-st.
205 inhibit ① " " " "...

St.St. $\boxed{-6.6, \; -4.0, \; \begin{cases} -3.2 \\ -3.2 \end{cases}}$

731.201 5/31/63

∴ Seek steady state information.

∴ avoid cpts 11, 12, 13 & 14
use out lambdas instead.

∴ No cmpts is set at 9

9 is set at −10. , also st. st. at −10.

hope this leads to other st. st. information, as built in by Mones.

$\sigma_{7,4} = 1.$
$\sigma_{7,9} = -1.$

also, use cpt. 7 as a summer and since do not yet know st. st. value of ④ let ⑦ give Q④ − Q⑨
later, want ⑦ to give Q④ − Q st. st. of 4

This is needed to best demonstrate the symmetries for J with $\beta \neq 0$ and I.C. interchange with obs. pt.

In this problem, all compartments are of equal size!

$J = 5$ in ④

∴ $\lambda_{0,4} = 6.$; $\lambda_{4,9} = 5.$; $\lambda_{0,9} = -5.$

Imin

in ⑤

①or⑤ peak = 4.940 at T = 0.36

②or④ peak = 5.58808 at T = 0.38

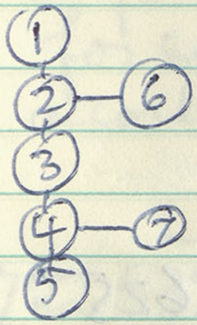
③ peak = 5.57864 at T = 0.40

T	in ③		in 2or4
.36	.555279	<	.557660
.38	.557616	<	.558808
.40	.557864	≃	.557865
.42	.556292	>	.555122
.44	.553139	>	.550835

with cpt. 8 attached to ③
peak in ③ becomes 2% greater than peak in ②or④

731.301 5/31/63

To test hypothesis that J is more effective when λ_{ii} is smaller because less junctional.



Put I.C. in ①

Observe in ⑤

Use J with $E_j = E_r$ ($\beta = 0$)

Predict that J in ① & J in ⑤ are most effective & equally so.

Predict that J in ② & J in ④ will be equally effective, but less effective than J in ③ because ③ does not have a side compartment.

Here made $\lambda_{ij} = 16$.

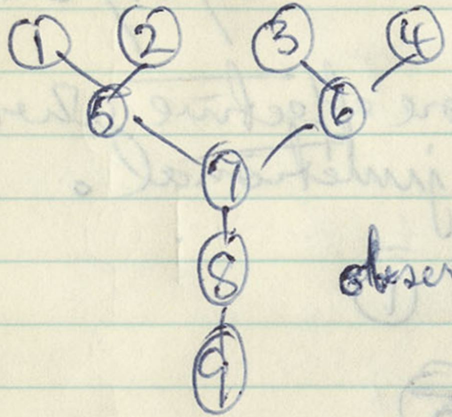
∴ $\lambda_{11} = \lambda_{55} = 17$.

$\lambda_{33} = 33$.

$\lambda_{22} = \lambda_{44} = 49$.

Predict J = 5 would be more effective in ③ than in ② or ④

But how about J = 16 or greater? or J = 5 with $\lambda_{ij} = 4$



observe 8

$\lambda_{6,7} = \lambda_{5,7} = \lambda_{1,5} = \lambda_{2,5} = \lambda_{3,6} = \lambda_{4,6} = 0.625$

other $\lambda_{ij} = 1.25$

as before

But ~~for~~ $J = 2$ in 1, 2, 3, or 4 $\Delta\lambda = 0.1$

comparable $J = 1$ in 5 or 6 $\Delta\lambda = 0.05$

comparable $J = 1/2$ in 7, 8 or 9 $\Delta\lambda = 0.025$

also, $\boxed{\lambda_{1,10} = 0.025}$

but this is important only if ~~first~~ connect
Source also to other compartments.

722.532 - 535 5/31/63

These were run May 22 & 27

Purpose was to correct 722.500 series for earlier failure to correct values of g according to size of compartment.

all have ε pulse in ① ($\varepsilon=2$) or I.C. in ①

722.532 A. $g=2$ in ① sustained peak = 1.4256
error B. $g=$ ② in ⑧ sustained 1.5
C. I.C. with $g=\frac{1}{2}$ in ⑧ (1.7028)

722.533 A. $g=1$ in ⑤ 1.5016
B. $g=\frac{1}{2}$ in ⑦ 1.5286
C. I.C. $g=2$ in ① (1.5839)

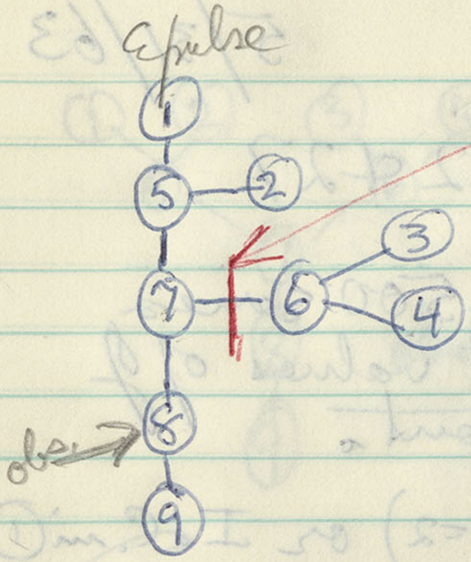
722.534 A. $g=2$ in ② 1.5239
B. $g=1/2$ in ⑧ 1.5249
C. I.C. $g=\frac{1}{2}$ in ⑦ (1.7067)

722.535 A. $g=1$ in ⑥ 1.55012
B. $g=2$ in ④ 1.5585
C. I.C. $g=1$ in ⑤ (1.676)

later

722.536 A. $\varepsilon=\frac{1}{2}$, $g=\frac{1}{2}$ in 1, 2, 3, 4 1.597
B. $g=\frac{1}{2}$ in 9 with $\varepsilon=2$ in 1 1.5397
C. $g=\frac{1}{2}$ in 9 1.72

see also 537, 538, later (6/26/63)



This cut off in 722.239 7/1/63

Then J become more effective in ⑦ than in ⑤

This done for equal cpts.

test this by putting J = 1/2 in ⑤ & ⑥ with E = 1/2 in 1, 2, 3, 4 See 722.537, 536 } 6/26/63

⑤ beats ⑧ because more conc. J, ∴ Δλ/λ is larger

② improved because more conc. J

Still some puzzles here ?

722.532 - 535 Summary

$K = 0$
$\mathcal{E} = 2$ in ① for $\Delta T = 0.25$
J is sustained at different sites

	$\mathcal{E}$ pulse in ① peak	I.C. in ①
J = 2 in ①	1.4256	1.5839
= 1 in ⑤	1.5016	1.676
J = 2 in ②	1.5239	
J = ½ in ⑧	1.5249	1.7028
J = ½ in ⑦	1.5286	1.7067
⑨	< 1.540	⑨ 1.72
J = 1 in ⑥	1.55012	
J = 2 in ④	1.5585	
Control	1.568	1.747

Order here is 1, 5, 2, 8, 7 (close together) 6, 4 (close)

Order in 722.200 series was 1, 8, 5, 7, 2 (Equal Cpt. Size)

In both series ① is first — probably because λ_{11} is smallest

⑤ is better than ⑦ — why? Perhaps because ⑦ carries a larger load (6, 3, 4) could explain this

~~⑧ is better than ⑦~~ — in equal cpt case $\lambda_{88} < \lambda_{77}$ but not when $K = 0$

← See 722.239 7/1/63 for equal cpts.

Note: Steady states given below each peak, in pencil

~~In~~ These cases, where J & E are both at ①
(although E is for $\Delta T = 0.25$ and J is
sustained)

it is as though $E = 10$ during $\Delta T = 0.25$

with source $G_{st} = 100(1+\beta)/2$

consequently, peak in ①, which occurs at $T = 0.25$ is affected only by this, and is

10% higher for $\beta = +0.1$ than for $\beta = 0$
10% lower " -0.1 " " " "

However peaks in ③ & ④ occur later

peak in ③ occurs at $T = 0.30$
④ $T = 0.40$ to 0.50

and these must now be referred to st. st. effects of J

Effect in ③ & ④ is more than 10%, but is in same direction as before.

Greater because J has more time to act

Summary of 731.100 series to date. 6/3/63

731.101 — 731.116

E pulse in ① with Cpt. 8 set at 100

J location & $\beta = 0, +0.1, -0.1$

	Peak in ①	③ at T=0.25	Peak in ③	④ at T=0.25	Peak in ④
Control st.st.	49.45 0.		15.81 0.		10.30 0.
J in ① $\beta=0$ .111	34.71 0.	10.64	10.9 0.	3.74	6.163 0.
" $\beta=-0.1$ .105	31.24 -6.6	9.572	9.64 -4.0	3.37	5.26 -3.2
" $\beta=+0.1$ .115	38.18 +6.6	11.70	12.16 +4.0	4.12	7.165 +3.2

$$\begin{array}{r} 34.71 \\ -31.24 \\ \hline 3.47 \end{array} \quad \begin{array}{r} 10.64 \\ 9.57 \\ \hline 1.07 \end{array} \quad \begin{array}{r} 10.9 \\ -9.64 \\ \hline 1.26 \end{array} \quad \begin{array}{r} 3.74 \\ 3.37 \\ \hline .37 \end{array} \quad \begin{array}{r} 6.163 \\ -5.26 \\ \hline .903 \end{array}$$

$$\begin{array}{r} 38.18 \\ -34.71 \\ \hline 3.47 \end{array} \quad \begin{array}{r} 11.70 \\ 10.64 \\ \hline 1.06 \end{array} \quad \begin{array}{r} 12.16 \\ -10.9 \\ \hline 1.26 \end{array} \quad \begin{array}{r} 4.12 \\ 3.74 \\ \hline .38 \end{array} \quad \begin{array}{r} 7.165 \\ 6.163 \\ \hline 1.002 \end{array}$$

These peaks occur at different times

Note: for both $\beta=0$
& $\beta=-0.1$

J in ④ is more effective than
J in ① when obs. in ④

for $\beta=0$, this is because of non linear addition of perturbations in ①
as compared with I.C. in ①

for $\beta=-0.1$
this is primarily due to effect of β sink.

6/3/63

Summary 731.100 Series Continued

	Peak in ①	③	④
Control st st.	49.45 0.	15.81 0.	10.30 0.
J in ④ $\beta=0$	49.42 0.	15.32 0.	5.55 0.
" $\beta=-0.1$	49.06 -3.2	13.68 -4.0	-0.08 -6.6
" $\beta=+0.1$	49.77 +3.2	17.09 +4.0	11.22 +6.6

49.42 -49.06 0.36	15.32 -13.68 1.64	5.55 +0.08 5.63
49.77 -49.42 0.35	17.09 -15.32 1.67	11.22 -5.55 5.67

Note that these come out above control level. In effect, we have spatial summation here.

i.e. not much interference between E & J.

see 731.118

essentially summation

to check this, may need to get transient for J alone. Probably there is interference at ①, but perhaps not much.

in other words epsp & ipsp should add simply when their sites are well separated.

Comparing 731.116 with 731.114 plus 731.118
shows almost perfect summation in pts ③ + ④
pretty close in pt. ①

Note: That $\lambda_{0,4}$ is equal to 5. in all
three of these

The difference is that the E pulse is present
in 731.114 without $\beta = +0.1$

Whereas $\beta = +0.1$ without the E pulse in 731.118

6/3/63

Summary 731.100 Series Continued

		Peak in ①	③	④
Control		49.45	15.81	10.30
J in ③	$\beta = 0$	48.71	11.3	6.68
"	$\beta = -0.1$	47.6	7.62	4.05
"	$\beta = +0.1$	49.79 T=.25	14.99 T=.3	9.54 T=.55

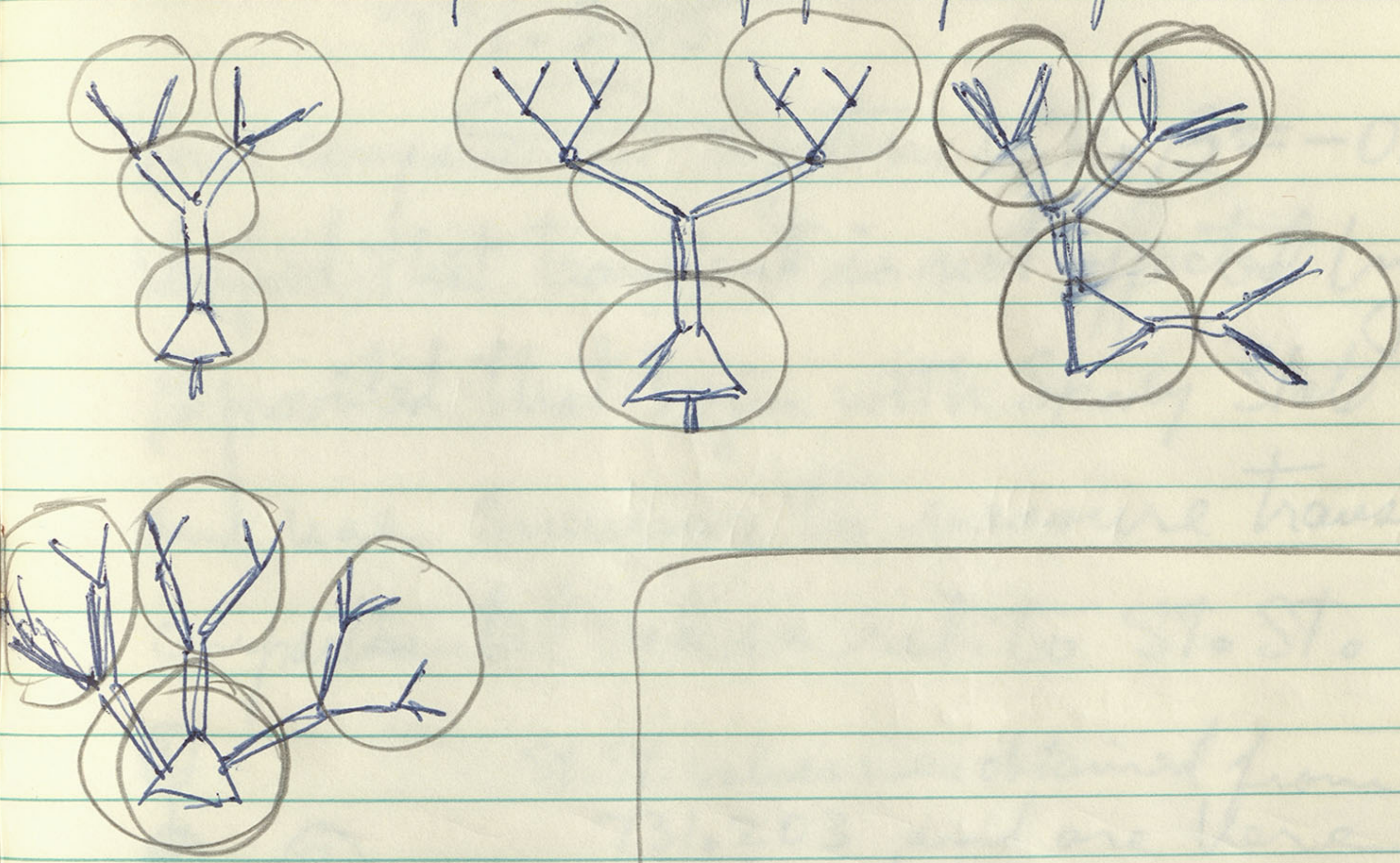
↑above control
i.e. there was summation

Control E pulse in ①	49.45	15.81	10.30
731.114 with J = 5 in ④ with $\beta = 0$	T=.25 49.4174	T=.30 15.3156 15.26 .35	T=.45 5.55 5.46[illegible] T=.50
731.118 Only J = 5 in ④ with $\beta = +0.1$	.474	1.66(.30) 1.87(.35)	5.67 (.45 5.77(.50
Sum of ◯	49.89	17.13	11.23
To be compared with E pulse with J = 5 in ④ with $\beta = +0.1$ 731.116	49.77	17.09	11.22

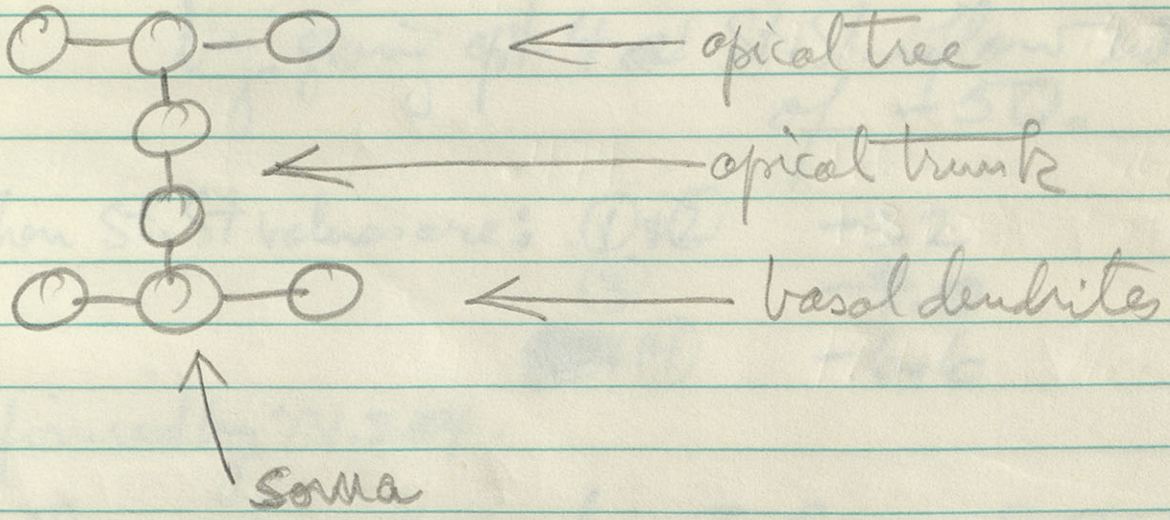
almost perfect summation

6/20/63

Various interpretations of four cpt. system



Pyramidal Cell

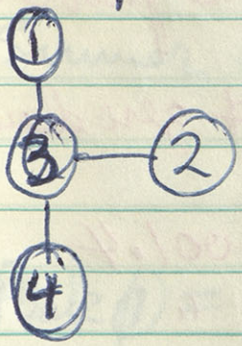


* 6/20/63

Results 731.204
731.205

Four compartment system with $\beta = -0.1$

Verified that transient is not affected by β provided that begin with Steady State and use summer to measure transient compartmental values rel. to St. St.



St. St. values were obtained from 731.203 and are here confirmed.

for J = 5 in ④, St. St. is obtained by giving cpt. 4 @ St. St. inflow entry of -50.

Then St. St values are: ①&② -3.2
③ -4.0
④ -6.6

confirmed by 731.204:

These values also used as I.C., except that in ①, I.C. = 90-3.2 = 86.8

Note that transient in ④ is entirely neg.

However, transient in ⑦ [i.e. ④ rel to st. st.] agrees exactly (6 significant figures) with ④ of 731.001.4 which is the same problem for $\beta = 0$, with I.C. of 90. in ① & zero elsewhere.

Similary ⑤ agrees exactly with ③ of 731.001.4
⑥ " " " ① " "

Also, because of symmetry between
731.001.1 and 731.001.4,

and 731.204 and 731.205

Cf. ⑦ here agrees also with ⑦ of 731.205

and with cpt. ④ in 731.001.1
for J = 5 in ①

731.204 6/20/63

I.C. ① 86.8
② −3.2
③ −4.0
④ −6.6

preestablished st st.

$J = 5$ in ④ sustained

$\beta = -0.1$

Sink compartment ⑨ set at −10.

Summer ⑦ designed to give ④ +6.6

$\therefore \sigma_{7,4} = 1.0$, $\sigma_{7,9} = -0.66$

Summer ⑥ designed to give ① +3.2

$\therefore \sigma_{6,1} = 1.0$; $\sigma_{6,9} = -0.32$

Summer ⑤ designed to give ③ + 4.0

$\therefore \sigma_{5,3} = 1.0$, $\sigma_{5,9} = -0.4$

Peak ① = 86.8 at T=0 ; Peak ⑥ = 90.

Peak ③ = 13.49 at T=.16 ; Peak ⑤ = 17.49

Peak ④ = −0.435 at T=0.32 ; Peak ⑦ = 6.164

Peak ② = +7.33 at T = 0.42

due to δ fcn

This verifies, to six sig. figures, that, transients measured rel. to pre-established st. st., are the same regardless of β value. The effect of J upon the "outlambda" must of course be the same, for the system to be the same.

Transient in ⑦ agrees with ④ of 731.001.1
and of 731.001.4

and with ⑦ of 731.204

Also ⑤ agrees with ③ of 731.001.1

and ⑥ agrees with ① of 731.001.1

All these agreements for 6 sig. figures

731.205

6/20/63

I.C. ① 83.4
② -3.2
③ -4.0
④ -3.2

preestablished st. st.

j = 5 in ①
sustained

$\beta = -0.1$

sink cpt. ⑨ set at -10.

~~Summer~~ ⑦ gives ④ +3.2

∴ $\sigma_{7,4} = 1.0$, $\sigma_{7,9} = -0.32$

~~Summer~~ ⑥ gives ① +6.6

∴ $\sigma_{6,1} = 1.0$, $\sigma_{6,9} = -0.66$

~~Summer~~ ⑤ gives ③ +4.0

∴ $\sigma_{5,3} = 1.0$, $\sigma_{5,9} = -0.40$

Peak ① = 83.4 at T=0

Peak ⑥ = 90.

Peak ③ = 8.466 at T=.1

Peak ⑤ = 12.466

Peak ④ = 2.964 at T=0.32

Peak ⑦ = 6.164

Peak ② = 2.964 at T=0.32

731.204 & 205 6/20/63

Two general conclusions from this experiment

A. Rel to St. St. effect of J, ~~[illegible]~~ effect of J on δ transient is independent of β.

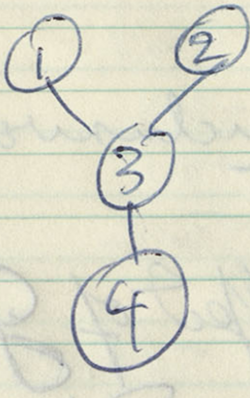
Whether this is true also for E pulses will be checked out in 731.121
731.124
(see next page)

I predict that it will be true, because β = 0 will have the same E-J interference in compartment ① as β = -0.1

Answer is No!
See two pages over

B. Regarding membrane potential β = -0.1 has the most effect when J is at the recording site, or functionally at the trigger zone.

This is sustained J. presumably even more true for brief J



11, 12, 13, 14

Summers

6/20/63

Setup 731.121
.124

Begin with two decks from 731.100 series

However, Compartments ⑪, ⑫, ⑬, ⑭
have been converted to Summers

They are no longer collecting compartments.
"Out lambdas" have been restored,
and made dependent upon E + J

i.e. $\lambda_{o,i} = 1 + \lambda_{i,8} + \lambda_{i,9}$

Also, St. St. initial conditions have been introduced, and a st. st. inflow has been entered to check this.

for this reason $\lambda_{1,9} = 5.$ in 731.121

and $\lambda_{4,9} = 5.$ in 731.124

in order that correct λ_{oi} would be used in the St. St. calculation.

Apparently the effect of Initial Conditions upon the E pulse prevents ⑭ from agreeing with ④ of 731.111 and 731.114

↓ 6.163 ↓ 5.655

I.C. set at st. st.

6/24/63

731.121 J=5 in ① sustained $\beta = -0.1$
E pulse in ① square

					T
Peak in ①	30.4045	⑪	37.0		.25
③	7.619	⑬	11.62		.30
④	3.37	⑭	6.57		.45

These all run longer than for $\beta = 0$ 731.111

731.124 J=5 in ④ sustained $\beta = -0.1$

				T
Peak in ①	47.80	⑪	51.0	.25
③	11.8	⑬	15.8	.30
④	-.87	⑭	5.73	.45
②	6.72	⑫	9.92	.55

These values all run longer than case for $\beta = 0$ 731.114

J=5 in ③ is more →
effective than in ② or ④

Unexpected degeneracy for J in ② or ④
when observe ④ with I.C. in ①

Results of 731. 300 Series

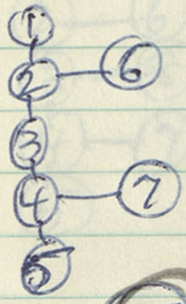
6/25/63

See also 305

$\lambda_{ij} = 16.$

J = 5. in various locations.

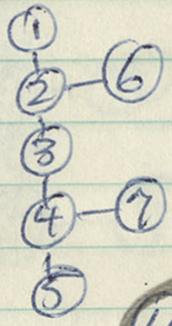
731.301



observe ⑤

I.C. in ① each time

731.304



observe ④

I.C. in ②

I.C. in ① all except first time

Control 8.43 at T=.32

J location	Peak Ampl.	Time	Peak Ampl.	Time
①	4.940	.36	7.48 (I.C. in ②)	.24
②	5.588	.38	6.071	.30
③	5.5786	.40	6.049	.32
④	5.588		6.071	.30
⑤	4.940		6.88	.32

compare with 731.302 next page where J in ③ is least effective

Here J=5 in ③ is more effective than at site of recording ④

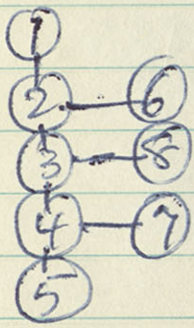
Must be λ_{ii} effect

approx 2%

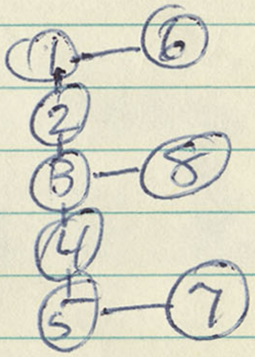
J = 5 in ③ is less effective than in ② or ④

6/25/63

731.302



731.303



observe ⑤
I.C. in ①

Location	Peak Ampl.	Time	Peak Ampl.	Time
①	4.318	.42	3.996	.46
②	4.924	.42	4.204	.48
③	5.046	.44	4.343	.48
④	4.924	.42	4.204	.48
⑤	4.318	.42	3.996	.46

these are consist. lower than those at left, must be due to different assortment of connections.

731.305 similar to 731.304

Observe in ④
I.C. in ② for every case
Control without J is 8.43 at T=0.32

J location	Peak Ampl.	Time
① (from 304)	7.484	.24
②	6.606	.22
③	6.482	.30
④	6.606	.22
⑤	7.484	.24

J in ③ is most effective

Perfect agreement for J in ② or ④
or for J in ① or ⑤

Degeneracy confirmed
but this degeneracy not ~~un~~expected

for I.C. in 1, 2, 3, 4

J = 1/2 in 5 & 6 or J = 1/2 in ⑧

gave precisely the same transient in ⑧

722.538 722.537

This is an interesting degeneracy similar to that of 731.304

Conjecture on generalization of same

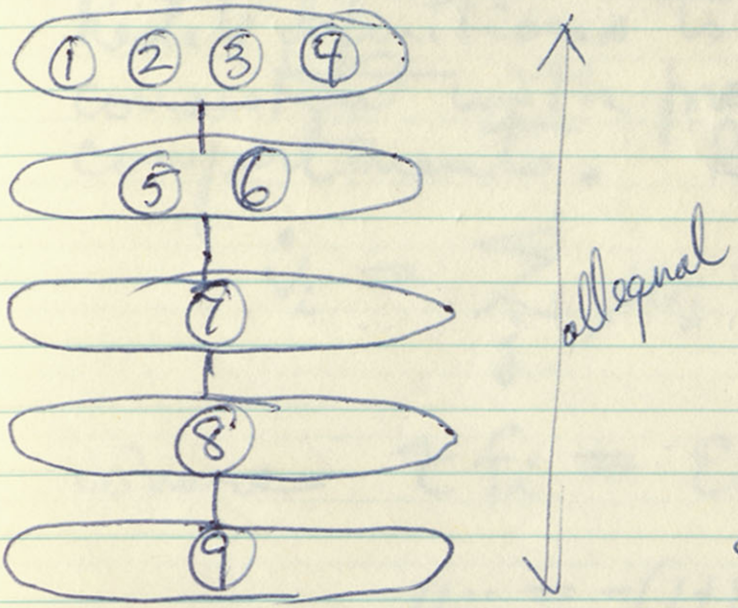
e.g.

① I.C. in ①
② observe ⑤
③ degeneracy for J in { ② or ⑤
④ { ③ or ④
⑤
⑥ λ_{ij} need not be equal

Only require $\lambda_{12} = \lambda_{65} \underset{\uparrow \text{optional}}{\neq} \lambda_{21} = \lambda_{56}$

etc.

722.536 – 538 K=0 6/26/63



1,2,3,4 / 5,6 } lumped

$\varepsilon = 1/2$

Square ε pulse in 1,2,3&4

Observe peak in ⑧

722.536	J = 1/2 in 1,2,3&4	1.5970
722.537	J = 1/2 in 5&6	1.61047
722.538	J = 1/2 in ⑦	1.61411
722,537	J = 1/2 in ⑧	1.61024
722.538	J = 1/2 in ⑨	1.62583

J most effective in 1234 because ⑧ is not an end cpt.
J in ⑧ only trivially better than J in 5&6
(for I.C. in 1,2,3,4 ~~these~~ agree exactly)
J in ⑦ only slightly less effective, presumably because farther from ends
J in ⑨ least effective because other side of ⑧ from source

6/26/63

Restate definitions to be consistent with problems having unequal compartments. Re Ojai Paper

$$\dot{V}_i = \sum_j \mu_{ij} V_j + f_i$$

where $\tau f_i = \mathcal{E}_i + \beta J_i$ (in absence of electrodes)

$$\mu_{ii} = -(1 + \mathcal{E}_i + J_i)/\tau - \sum_{j \neq i} \mu_{ij}$$

$$\left(\mu_{ij} = \frac{g_{ij}}{C_i} = \lambda_{ji} = \frac{C_j}{C_i} \mu_{ji} = \frac{C_j}{C_i} \lambda_{ij} \right)$$

$$\dot{q}_i = C_i \dot{V}_i = C_i \sum_j \mu_{ij} V_j + C_i f_i$$

$$= \sum_j \lambda_{ij} q_j + \lambda_{i,8} q_8 + \lambda_{i,9} q_9$$

where 8 refers to source compartment
9 sink

and $q_8 = C_8 *$ Scale factor (e.g. 100)

$\lambda_{i,8} = \frac{C_i}{C_8} * \mathcal{E}_i$

$q_9 = C_9 *$ Scale factor $* \beta$

$\lambda_{i,9} = \frac{C_i}{C_9} * J_i$ $\quad C_9 = C_8$

This takes care of problem back at 5/20/63 overpage (tabbed) of 731.010 series

Then get rel. voltage as a dividend

& can use as ready reference for coefficients in depend relations

Why not use Kappas as reciprocal capacity rel. to largest = 8 & 9

let $\lambda_{i,\cancel{10}7} = \mathcal{E}_i$

$\lambda_{i,\cancel{11}10} = g_i$

write $\lambda_{i,8} = \left(\frac{1}{K_i}\right) \lambda_{i,\cancel{10}7}$

$\lambda_{i,9} = \left(\frac{1}{K_i}\right) \lambda_{i,\cancel{11}10}$

This pushes program limitations too much

$$\lambda_{1,2} = \left(\frac{C_1}{C_2}\right) \lambda_{2,1} = \left(\frac{K_2}{K_1}\right) \lambda_{2,1}$$

Then $\lambda_{0,i} = 1 + \lambda_{i,70} + \lambda_{i,10}$ without qualification

When all compartments are equal $\frac{c_i}{c_8} = 1 = \frac{c_i}{c_9}$

and $\lambda_{i,8} = \varepsilon_i$ ~~[illegible]~~

$\lambda_{i,9} = J_i$

Otherwise, need to use capacity ratios.

Problem, how to build this in by means of dependence relations.

~~11~~

Let compartment **10** be empty

~~Let $\lambda_{i,10}$ specify~~ ~~[illegible]~~ compartment capacity size relative to 8 = 9 which might as well be set equal to largest cpt.

~~$\lambda_{i,11}$ specifies~~

~~[illegible] $\lambda_{1,3} = c_3$~~

~~[illegible] $\lambda_{1,2} = c_2$~~

Specify $\lambda_{2,1}$, $\lambda_{3,2}$ and $\lambda_{4,3}$

For symmetric situation

Dependence relations: $\lambda_{5,6} = 1 * \lambda_{2,1}$

$\lambda_{1,2} = \left(\frac{c_1}{c_2}\right)\lambda_{2,1} =$ ~~$\left(\frac{\lambda_{1,10}}{\lambda_{2,10}}\right)\lambda_{2,1}$~~

coefficients in dependence relation

$\lambda_{3,4} = \lambda_{4,3}$

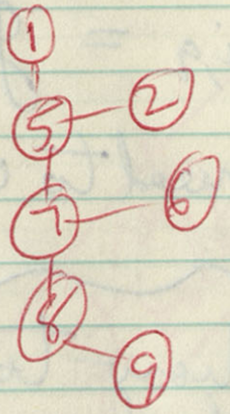
$\lambda_{6,5} =$ same

$\lambda_{4,5} = 1 * \lambda_{3,2}$

$\lambda_{2,3} = \left(\frac{c_2}{c_3}\right)\lambda_{3,2} =$ ~~$\left(\frac{\lambda_{2,10}}{\lambda_{3,10}}\right)$~~ $\lambda_{3,4}$

also $\lambda_{5,4}$

b ~~B~~ includes ⑥ but cuts off ③ & ④



A. 3.8406

B. 3.8590

less effective at ⑦ than at ⑤

Note, degeneracy rule would have made these equal if ⑨ were not present.
∴ it is the addition of ⑨ which increases λ_{88}, which makes B slightly less effective at ⑦ than at ⑤

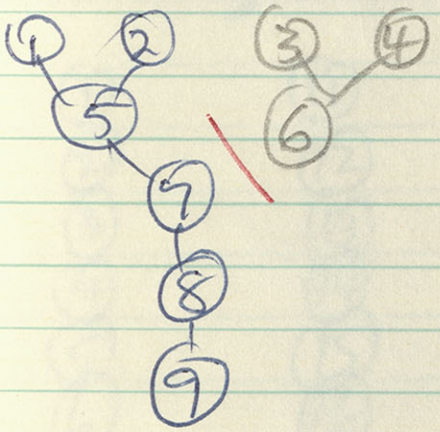
or if there were another cpt. added beyond ①

A4b

7/1/63

722.239 successfully run

equal cpt, but ⑥ cut off from ⑦



E = 2 in ① square

A. J=2 in ⑤ sustained

peak = 4.556

B. J = 2 in ⑦ sustained

peak = 4.534

(slightly more effective)

C. I.C in ①

J = 2 in ⑦

This proves that for whole tree J in ⑤ was more effective than J in ⑦ because ⑦ has a larger passive load.

see 7/10/63 for results

7/1/63

Wrote on 6/27/63 731.321 to begin a systematic test of degeneracies where compartments are unequal, but symmetrically arranged.

Two tests in One

① ⑪
② ⑫
③ ⑬
④ ⑭
⑤ ⑮
⑥ ⑯

observe { ④, ⑤, ⑥
⑭, ⑮, ⑯ }

for each of five time runs.
by means of dependence relations.

K=4. for ①, ⑥, ⑪ & ⑯
K= 2. for ②, ⑤, ⑫ & ⑮
K= 1. for ③, ④, ⑬ & ⑭

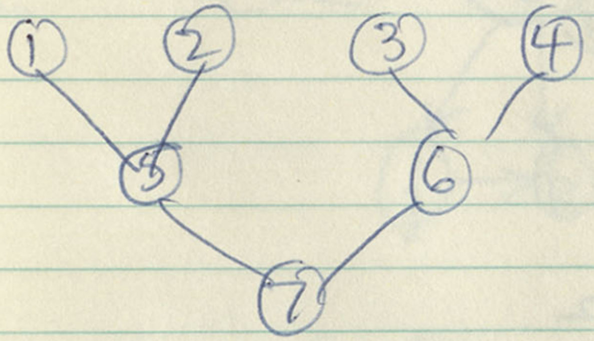
Also symmetric $\lambda_{12} = 4.$, $\lambda_{21} = 8.$
$\lambda_{23} = 6.$ $\lambda_{3\cancel{2}} = 12.$
$\lambda_{34} = \lambda_{43} = 16.$

Time Pattern

10	I.C. in	①	Control	⑫	control	20	Jin ③	③ I.C.	I.C. ⑬	Jin ⑭
11	Jin ①	①		⑪	Jin ⑬	21	Jin ①	③	⑫	Jin ⑪
12	Jin ⑥	①		⑪	Jin ⑭	22	Jin ⑥	③	⑫	Jin ⑯
13	Jin ②	①		⑫	Jin ⑫	23	Jin ②	③	⑫	Jin ⑬
14	Jin ⑤	①		⑫	Jin ⑮	24	Jin ⑤	③	⑫	Jin ⑭

Prepared 731.401 7/2/63

To begin to test epsp & ipsp summations for different locations, with $\beta = -0.1$



kappas = 4.

kappas = 2.

kappas = 1.

Source 8 set at 1.
Sink 9 set at -0.1

$\lambda_{15} = \lambda_{25} = \lambda_{36} = \lambda_{46} = \lambda_{57} = \lambda_{67} = 4.$

$\lambda_{51} = \lambda_{52} = \lambda_{63} = \lambda_{64} = \lambda_{75} = \lambda_{76} = 8.$

All λ_{0i} except λ_{04} are made explicitly dependent upon λ_{i8} and λ_{i9}. The dependence relations incorporate the kappas.

A. $J = 5.$ in ⑦ for $T = 0$ to $.25$, Then off

B. $\{$ $E = 4(2.5) = 10.$ in ① for $T = 0$ to $.25$
$J = 5$ in ⑦ for $T = .25$ to $.50$
Then off.

See 7/22/63

Try $\lambda_{41} = 1.$

$\lambda_{14} = (10.)*q_2$

$\lambda_{21} = (10.)*q_1$ perhaps should be less

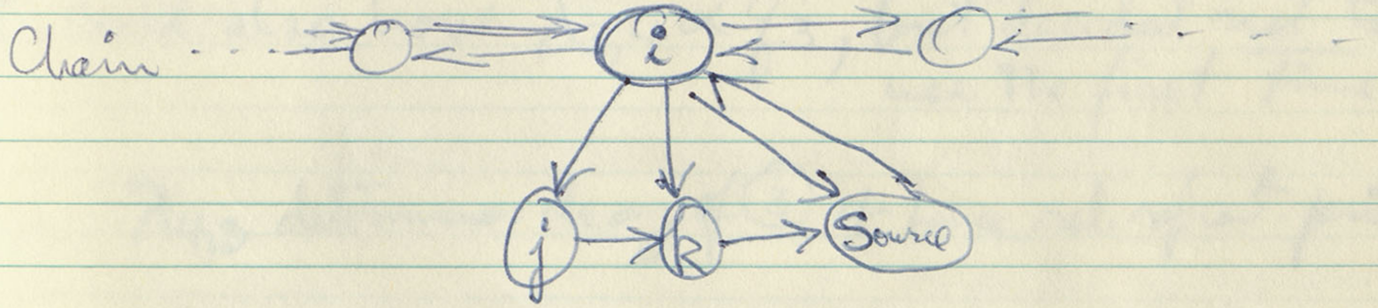
$\lambda_{32} = 5.$

$\lambda_{31} = (50.)*q_3$

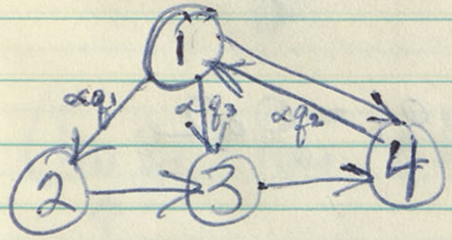
$\lambda_{43} = 2.$

If results are poor, consider putting in data and fitting parameters.

732.101 Begin to explore use of q-dependence to mimic an impulse. 7/3/63



Each cpt. needs two auxiliary cpts to provide delays & monitoring.



λ_{41} represents resting leak (insures no net loss to system)

$\lambda_{21} \propto q_1$ makes ② a non-linear, leaky integrator of ①

may wish to test need for this

↑ this should help to provide something like a threshold.

λ_{32} ~~only~~ helps determine time constant of ② & provides for first portion of delayed rise in ③

$\lambda_{14} \propto q_2$ provides regenerative Na in current analog

If ① + ② were in st. st. with $q_1 = 0.2$

then $k_{21}(.04) = k_{32}\, q_2$

$$q_2 = \frac{k_{21}}{k_{32}}(.04)$$

as q_3 begins to build up

$\lambda_{3,1} \propto q_3$ provides regenerative K out current analog.

* Could also have $\lambda_{3,4} \propto q_3$, but decided not to use the first time

$\lambda_{4,3}$ determines decay of ③ & hence rel. refract. period

Below threshold ~~$(k_{21} q_1 + k_{41})(q_1) <$~~

$$\underbrace{(k_{21} q_1}_{\text{keep this small}} + k_{41} + \underbrace{k_{31} q_3}_{\text{negligible}}) q_1 < k_{14} q_2 q_4$$

because $q_3 \simeq 0$
when q_1 below threshold

Suppose $q_1 = 0.2$ were just on threshold; $k_{41} = 1.0$

Then $(0.2\, k_{21} + 1.0 + ?)\, 0.2 \simeq k_{14} q_2 q_4$

Check calculation

See next page

No. steps for time, ΔT equals $(2.)(\lambda_{jj\,max})(\Delta T) + 1.$

Initially this should have been $(122)(.02)+1. = 2.44$ $\approx 4.$

No. of λ here was $6\lambda_{ij} + 4\underset{implicit}{\lambda_0} = 10.$

When $T = 0.08$, there had been four ΔT

$$\therefore \left[(8.)(\overset{\text{assuming const.}}{\lambda_{jj\,max}})(.02) + 4.\right] \times 10 > 3\times10^4$$

$$\text{or approx } (1.6)(\lambda_{jj\,max}) > 3\times10^4$$

$$\text{or approx } \lambda_{jj\,max} > 2\times10^4$$

This is a little puzzling, but suppose, for extreme case, $q_3 = 90.$, Then $\lambda_{31} = 45\times10^2$, which is not enough.

Also, this system is closed & should observe conservation of mass. $\therefore$ how can any compartment get more than 90.5

Moses says that when non-linear system blows up, this is precisely what does happen: conservation of mass can become grossly infringed by the iterative calculations.

This must be checked by cooling down the system and examining the early steps more finely. This is to be done with 732.103.

732.101 7/6/63

Actually set $\Delta T = .02$, $NT = 25$

$q_1(0) = 0.5$ first, next 0.1

+1. $q_2(0) = 0$

$q_3(0) = 0$

$q_4(0) = 90.$ first, next 90.

$\boxed{\text{zero iterations}}$

$\lambda_{41} = 1.0$

$\lambda_{14} = (10.)\, q_2$

$\lambda_{21} = (10.)\, q_1$

$\lambda_{32} = 5.$

$\lambda_{31} = (50.)\, q_3$

$\lambda_{43} = 2.$

neglecting q dependence

$\lambda_{11} = -61.$

$\lambda_{22} = -5.$

$\lambda_{33} = -2.$

$\lambda_{44} = -10.$

Diagnostics ① set $\pm 10^{12}$ at $T = .02$

② " " " " "

③ " " ~~~~

④ ~~~~~~

Lambdas * Steps exceed 3×10^4 at $T = 0.08$

Apparently blew up during iterations between $T = 0$ and $T = .02$ such that computation steps exceeded 3×10^4 by $T = 0.08$

In other words, the amount in at least one compt. became very large, so that its q dependent λ became very large, thus requiring very small steps.

In program $X = \text{largest } \lambda_{jj}$

$$YY = \frac{1}{2.*X}$$

$Y = \text{time interval}$

No. of steps for time $Y = \frac{Y}{YY} + 1.$

$= Y*2.*X + 1.$

Let us iterate 732.101 manually without Runge-Kutta to see how things should go. use $\Delta t = \frac{0.02}{4} = .005$

Initially, need consider only $\lambda_{21} = (10.)(.5) = 5.$
$\lambda_{41} = 1.$

$\lambda_{21} \Delta t = .025 \quad \times .5 = .0125$
$\lambda_{41} \Delta t = .005 \quad \times .5 = .0025$

get $q_1 = .5 - .015 = .485$
$q_2 = .0125$
$q_4 = 90.0025$ can neglect

Next step.
$\lambda_{41} \Delta t = .005 \times .485 = .002425$
$\lambda_{14} = .125 ; \lambda_{14} \Delta t q_4 = (.125)(.45) = .056$
$\lambda_{21} = 4.85 ; \lambda_{21} \Delta t q_1 = \underbrace{(4.85)^2}_{23.6} \times 5 \times 10^{-4} = .0118$
$\lambda_{32} \Delta t q_2 = (.025)(.0125) = .00031$

get $q_1 = .485 - .014 + .056$
$= .527$
$q_2 = .024$
$q_3 = .0004$
$q_4 = 89.94$

$J_{41} \approx .0026$
$J_{14} \approx .1$
$J_{21} \approx .014$
$J_{32} \approx .0006$
$J_{31} = (.02)(.005)(.53) = .00005$

get $q_1 = .61$
$q_2 = .038$
$q_3 = .001$
$q_4 = 88.94$

Next step
$J_{41} \approx .003$
$J_{14} \approx .17$
$J_{21} \approx .018$
$J_{32} \approx .01$
$J_{31} \approx (.5)(.005)(.61) = .00015$

get $q_1 \approx .76$
$q_2 \approx .046$
$q_3 \approx .011$
$q_4 \approx 72.$

Blow up is not obvious

See 7/22/63

Here $q_1(0) = 0.1$, then 0.4

$q_2(0) = .001$

$q_3(0) = .001$

$q_4(0) = 10.$

732.102 & .103 + .104 7/9/63

for 102 set up data for three cases: below, at + above thresh.
called for iterations
used different set of values: blew up.

Here $\Delta T = 0.1$ and $NT = 10$

(from what Mones says, this ΔT was much too large because the Runge Kutta step size could not be readjusted often enough, i.e. only at these ΔT intervals)

Also, here set $q_4(0) = 10^3$ which was too much

Here $\lambda_{41} = 1.$

$\lambda_{14} = (10.) q_2$ with range from 1. to 20.

$\lambda_{21} = (1.) q_1$ .1 10.

$\lambda_{32} = 5.$ 1. 10.

$\lambda_{31} = (10.) q_3$ 1. 20.

should change to 1.

$\lambda_{34} = (10.) q_3$ 1. 20.

$\lambda_{43} = 2.$ .2 10.

Lambdas * Steps exceeded 3×10^4 at $T = 0.2$
Cpts 1, 3 + 4 set at $\pm 10^{12}$ at $T = 0.1$

Set up .104 for zero iterations, similar lambdas
But with $\Delta T = 0.005$, $NT = 10.$

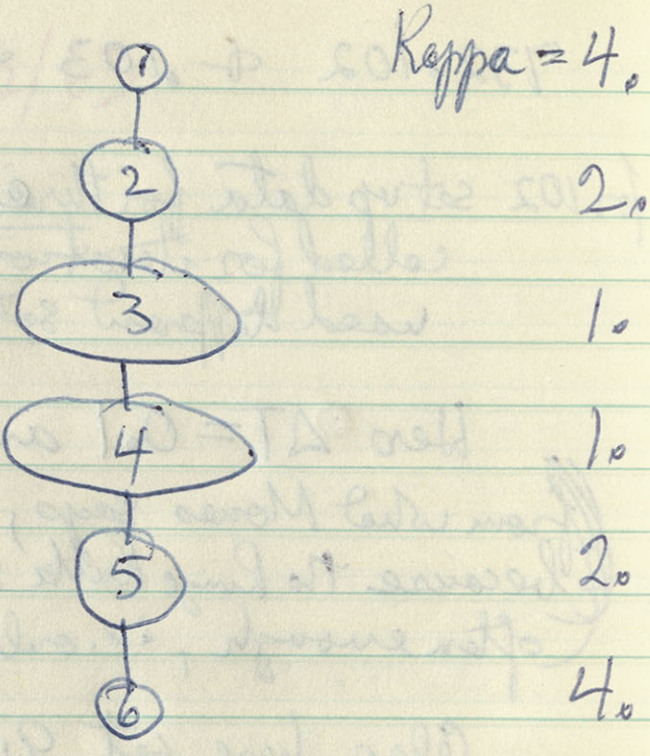
no observed values

.103 $\Delta T = 0.01$, $NT = 10.$
Q dependence eliminated as a control

$\lambda_{12} = 4.$, $\lambda_{21} = 8.$

$\lambda_{23} = 6.$, $\lambda_{32} = 12.$

$\lambda_{34} = 16. = \lambda_{43}$



Generalization

I
for each I.C. location
J in ① or ⑥ gave degen obs cpt. sym to I.C.

II
for I.C. in ① or ② but not ③
J in ② or ⑤ gives degen in both ⑤ & ⑥

III for I.C. in any location
J in ③ or ④ gives degen in ④ ⑤ & ⑥

7/10/63

Results of 731.321 & 322A&B
Testing Degeneracies.
See (7/1/63) for set-up

Summary of Results

I.C. in ①,	J in ① or ⑥	obs. identical transient in ⑥	of course also ①
	J in ② or ⑤	⑤ & ⑥	① & ②
	J in ③ or ④	④, ⑤ & ⑥	①, ② & ③
I.C. in ②,	J in ① or ⑥	⑤	②
	J in ② or ⑤	⑤ & ⑥	① & ②
	J in ③ or ④	④, ⑤, ⑥	①, ② & ③
I.C. in ③,	J in ① or ⑥	④	③
	J in ② or ⑤	④	③
	J in ③ or ④	④, ⑤ ⑥	①②③

731.322B revealed precisely same pattern for equal compartments & equal F_{ij}

Also note: for I.C. in ③

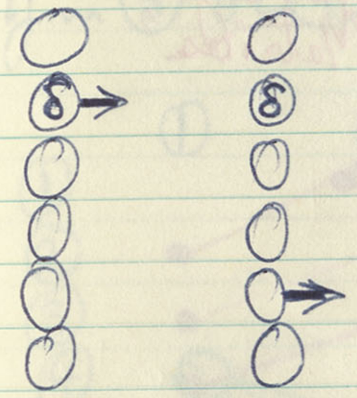
transient in ⑤ for J in ③ or ④

is same as

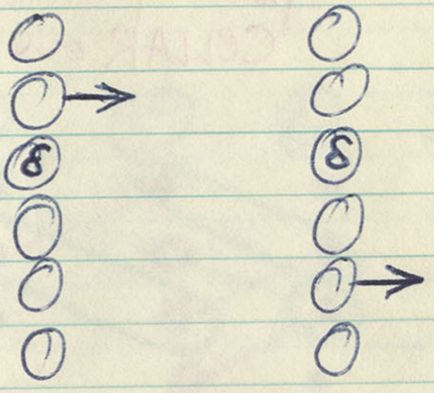
transient in ④ with I.C. in ②
and J in ③ or ④

7/10/63

Problems for intuition

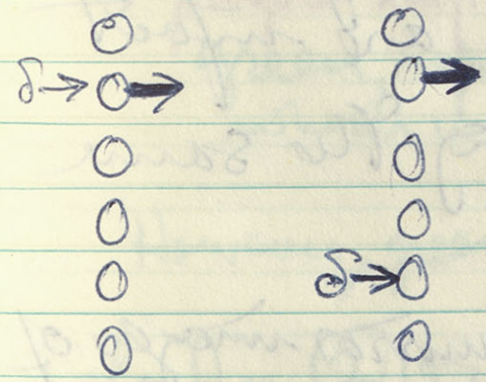


Same in ⑤
same in ⑥ !



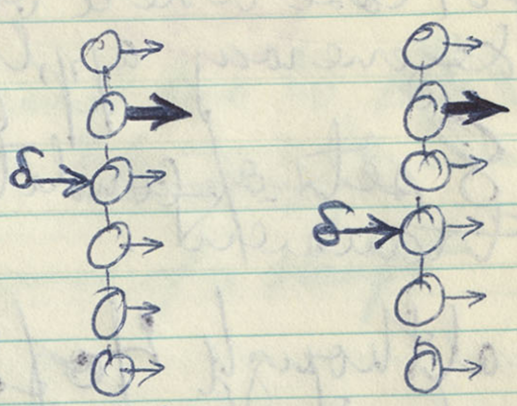
same in ④ but not 5 or 6

|||



obs 6 ≡ obs 1
obs 5 ≡ obs 2.

|||



obs ④ obs 3

Rerun with I.C. in shifted to opp-end: Found no further degen.

12/2/64

See page 76 of Book 5 for a reference to a possibly relevant Mathematical paper by COLLAR on "Cross Symmetric Matrices"

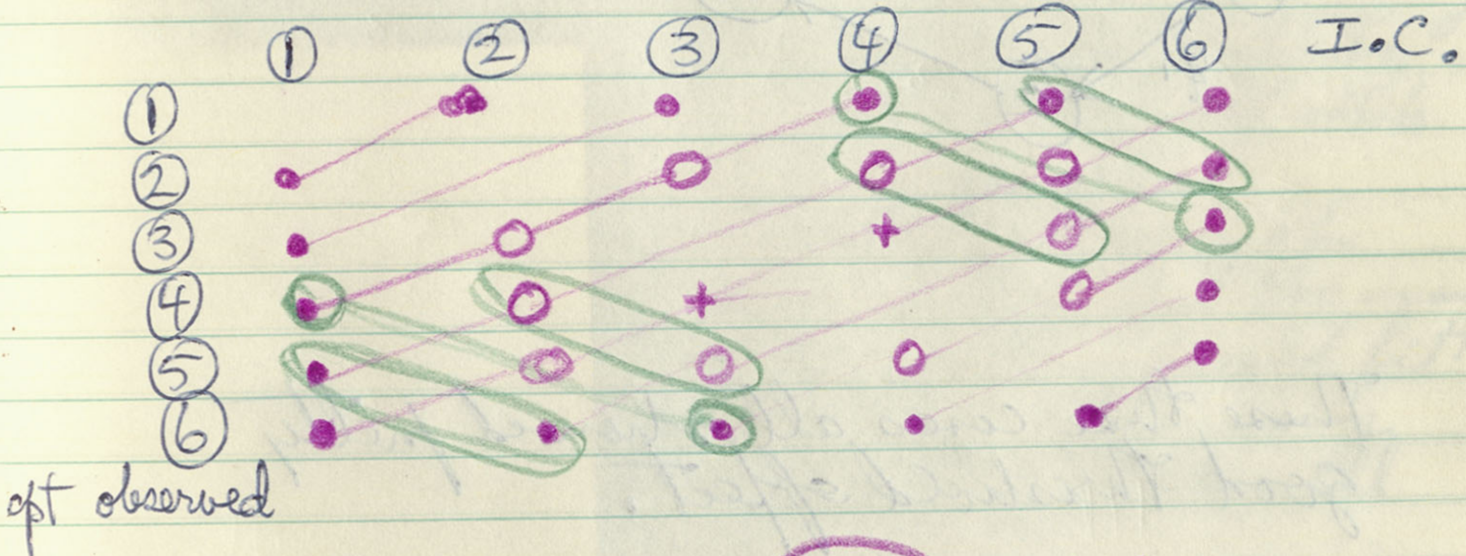
For case where both purple & green degeneracy apply. There are in fact 8 sets of conditions giving the same transient.

although 4 of 8 represent mirror images of first four.

First four result from { one pair due to I.C. des
{ doubling due to J interchange.

Degeneracies can be summarized as follows

for J in ③ or ④



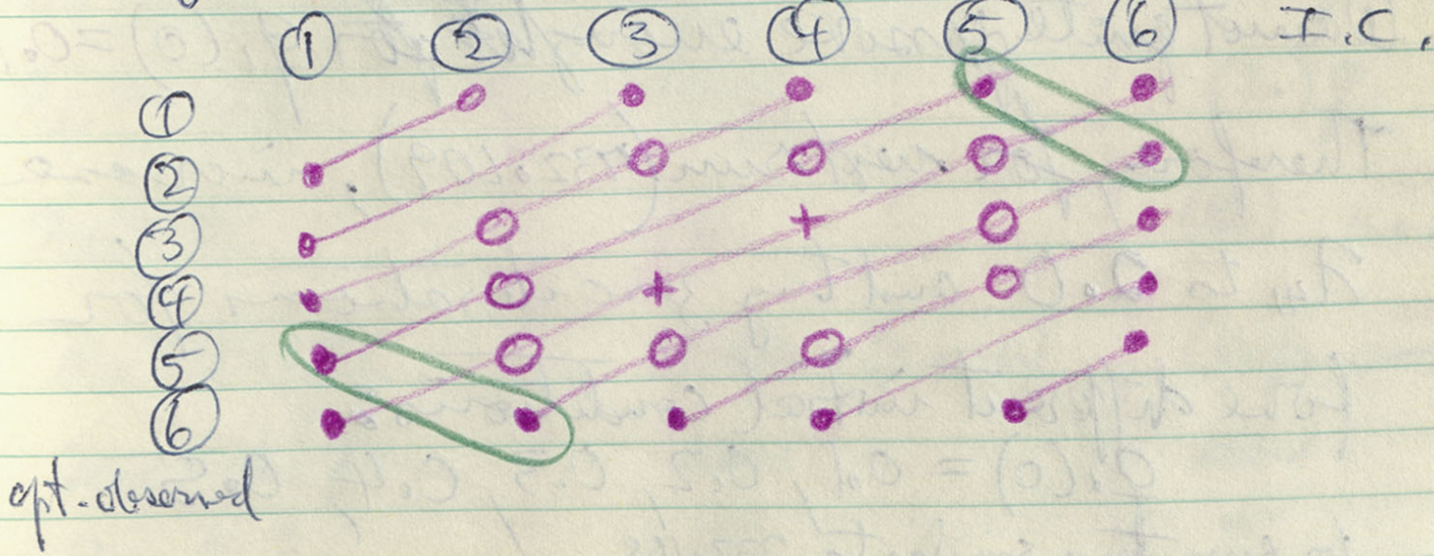
purple represent I.C. ↔ obs

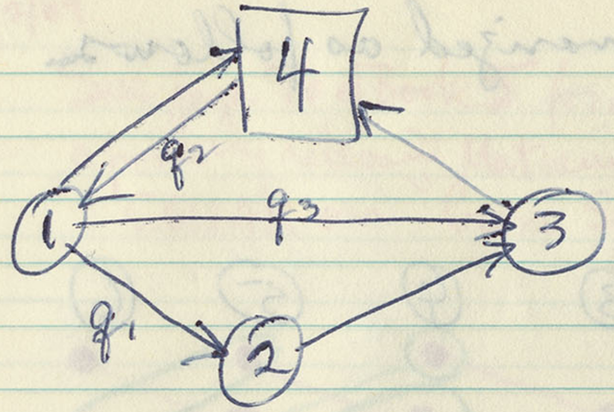
green represent additional due to J ↔ J

which works only when I.C. ↔ obs. includes J
~~range~~
if I.C. is not symm. to obs.

However, green has appearance of a **shift**

for J in ② or ⑤





These three cases all showed pretty good threshold effect.

$$q_1(0) = 0.1 \quad \text{vs} \quad q_1(0) = 0.3$$

and pretty good action potentials.

Latency to peak of .108 was approx half that for 107

Was not quite passive enough for $q_1(0) = 0.1$

Therefore, for next run (732.109), increase λ_{41} to 2.0 and try zero iterations for five different initial conditions:

$$q_1(0) = 0.1, \ 0.2, \ 0.3, \ 0.4, \ 0.5$$

for parameters similar to 732.108

Fri

Sugiura✓ — Matisse✓ et al.
Turner < 50's
JFF
Gillespie.

Chelsea < Sarelin
CV

prepare Fulton
Terry Dagradi
pencil - lab

MSS
Golji
Takas list
auto final

Harry Stout
Skip Stout
Frank Edw.

Glenda Gilmore civil rights
John Blum
Gaddis
John Lewis Gaddis' Cold War
Asa Briggs Victorian People

(Action Pot.)

7/22/63

Impulse model, using Q dependence

732.107 & 732.108 were successful, building upon what was learned by difficulties of 732.101 – 105 and partial success of .106

732.106 had initial estimates of parameters that were of correct rel. magnitudes, but too many were variable, to permit improved fit to the "data" points. ie. too many degrees of freedom ≡ fitting problem ill conditioned.

732.106	732.107	732.108
$q_4(0) = 10.$	$q_4(0) = 50.$	$q_4(0) = 50.$
$\lambda_{41} = 1.0$	1.1	1.1
$\lambda_{14} = (10.) q_2$ [illegible]	$(2.) q_2$ 1.83 $(1. \leftrightarrow 4.)$	$(4.) q_2$
$\lambda_{21} = (1.) q_1$	$(1.) q_1$	$(2.) q_1$
$\lambda_{32} = 5.$	6.	(10.) 15.4 $(5. \leftrightarrow 20.)$
$\lambda_{31} = (10.) q_3$	$(10.) q_3$ 15. $(5. \leftrightarrow 15.)$	$(10.) q_3$ 20. $(1. \leftrightarrow 20.)$
$\lambda_{34} = (1.) q_3$	deleted	deleted
$\lambda_{43} = 2.$	4.	5.

$g_1(0) = 0.1$

[illegible] pretty good as [illegible]

Attempted a peak of .108 [illegible]

Was not quite sensitive enough [illegible]

Therefore for next run (732.107), increase

[illegible] to 2.0 and try zero-level [illegible]

[illegible] different initial conditions

$g(0) = 0.1$, [illegible]

[illegible]

Setup ⊛ good

732.109

$\lambda_{41} = 2.$
$\lambda_{14} = (4.) q_2$
$\lambda_{21} = (2.) q_1$
$\lambda_{32} = 15.$
$\lambda_{31} = \boxed{20.} q_3$
$\lambda_{43} = 5.$

no iterations.

I.C. = 0.1 in ①	almost flat		
0.2	peak of 1.016	at T =	.6
0.3	1.196		.38
0.4	1.348		.28
0.5	1.515		.24

50. in ④ each time

Results showed that I.C. in ① remained cooler than in 108, but did rise very slightly.

Got good series with peak earlier ~~and~~ higher each time.

New provision should lock peak down more (Equilib-Pot.)

attempt to do without ③

732.110

cpt. ③ here serves only as a dump.

$\lambda_{04} = -\lambda_{14}$
$\lambda_{01} = 2.$
$\lambda_{14} = (4.) q_2$
$\lambda_{21} = (2.) q_1$
$\lambda_{02} = 15.$
$\lambda_{31} = (40.) q_2$
$(20. \longleftrightarrow 100.)$

Two iterations

lost threshold phenomenon, presumably because λ_{31} was not effective enough, perhaps also because ④ now held const.
Must be one of these because otherwise same as 109

Crucial to make λ_{31} depend on q_2 instead of q_3

	I.C. (.1) first time range		I.C. (.3) second time range	
	min.	final	max	final
732.111 initial param	.0748 at .38	.649 1.0	3.145 .74	2.86 1.0
final param	.0736 .4	.505 1.0	2.74 1.0	2.74 1.0 worse
732.114 initial param	.0054 1.		3.1 1.	
final param	.00067		.014 wrong way	
732.115 initial param	.0748 .38	.649 1.0	3.145 .74	2.86 1.0
final param	.07716 .36	.857 1.0	2.48 1.0	

Trouble seems to be that larger λ_{31} pulls down peak even more than final value. There may be a later peak, beyond time range explored.

~~7/10/63~~
8/6/63

8/6/63 ran 732.111, .114 & .115

mod. of 732.110
i.e. reduced λ_{14}
increased λ_{31}

basically only ① & ②
③ is a dump.

$\lambda_{04} = -\lambda_{14}$
$\lambda_{01} = 2.$
$\lambda_{14} = (2.)\, q_2$
$\lambda_{21} = (2.)\, q_1$
$\lambda_{02} = 15.$
$\lambda_{31} = (100.)\, q_2$ range 50. to 150.

Iterations yielded (150.)
i.e. max. pulldown

$q_4 = 50$

Below thresh started to rise near end. / Probably should increase the value of λ_{01} maybe also of λ_{02}

Also spike did not come down. Why not?
It came down in 732.110

732.114 9/12/63

increase λ_{01} to 4.
adjusted to 5.7
which was too much

increase this to 200.

this lost threshold

Next 732.115 9/16/63
with
$\lambda_{01} = 2.$; range 1. to 10.
$\lambda_{31} = 100.\, q_2$, range 50. to 200.

went to $\lambda_{01} = 1.847$
$\lambda_{31} = 200.\, q_2$
But this was not really an improvement.

It seems that need
q. ③ as well as ②

These λ were estimated from 732.109 where $q_4 = 50.$ and peak of q_1 was not tied down

But not good enough

Next try

732.113

9/12/63

also got overflow

$\lambda_{04} = -\lambda_{14}$

$\lambda_{14} = (200.)\,q_2$

$\lambda_{01} = 4. + \lambda_{14} + (100.)\,q_3$ ← $10.\lambda_{31}$

$\lambda_{21} = (2.)\,q_1$

$\lambda_{32} = 5.$

$\lambda_{02} = 10.$

$\lambda_{03} = 5.$

$\lambda_{31} = (10.)\,q_3$

$\lambda_{01} = 4. + (1.)\,\lambda_{14} + (10.)\,\lambda_{31}$

732.116 9/16/63

tried again with $\lambda_{14} = 40.$ but again got overflow

8/6/63 ran 732.112 , .113 & .116

Here, held $q_4 = 1.0$
Aimed to set away (equilib) $q_1 = 1.0$

$\lambda_{04} = -\lambda_{14}$
$\lambda_{14} = (150.) q_2$
$\lambda_{21} = (2.) q_1$
$\lambda_{32} = 4.$
$\lambda_{02} = (3.) q_3$
$\lambda_{03} = 5.$
$\lambda_{01} = 2. + (0.9) \lambda_{14} + (10.) \lambda_{31}$
$\lambda_{31} = (3.) q_3$

$$\dot{q}_1 = (150.) q_2 - (2.) q_1 - \underset{\uparrow}{(135.)} q_2 q_1 - (30.) \underset{\uparrow}{q_3} q_1$$

should be 150. to be absolutely limiting.

This blew up.

This is for additional quench.

$$\dot{q}_2 = (2.)(q_1)^2 - (4.) q_2 - (3.) q_2 q_3$$ needs more loss

Trouble due to fact that Q_2 dependence of λ_{14} was not carried over to λ_{01} (i.e. program limitation)

Note that the ideas behind this model were developed separately & further in the following series

WXR 701C	8/5/63
WXR 703C	10/1/63
WXR 706C	10/16/63
WXR 707C	11/7/63
WXR 709C	11/19/63

details are in other notebook #3

11/8/63 732.125 attempt to correct blow up

11/19/63 732.126 finally succeeded in overcoming blow up

failure of 732.125 was due to fact that λ_{04} dependent upon λ_{14} lost the dependence of λ_{14} upon Q_2

This was corrected in 732.126 which provided for

λ_{14}	200.	Q_2
λ_{04}	-200.	Q_2
λ_{51}	200.	Q_2
λ_{01}	2.	
λ_{21}	2.	Q_1
λ_{32}	5.	
λ_{02}	10.	
λ_{03}	5.	
λ_{31}	10. range 1. to 50.	Q_3

Could have had λ_{04} $\quad$ 21

also Q dependent $\quad$ dependent

but this would not have worked for λ_{01} because there need a linear combination, hence, use λ_{51}.

for $\lambda_{31} = (10.)\,Q_3$, got peak of .7288 at $T = .72$

adjusted to $\lambda_{31} = (19.7)\,Q_3$, got peak of .5744 at $T = .54$ because of stronger quench

& this did come nearer to fit the data

October 1963

Began 732.200 Series Branchlet GE

and 732.300 PHR-Model-1

↑photoreceptor model

Notes left loose at the time
Today (5/16/66) still loose

5/21/63

Problem of using Mone's program for my problems when compartments are not all of equal size.

Difficulties arise in the present system because when

$\lambda_{i,\text{source}}$ is quartered for quarter size cpt

Then $\lambda_{0,i} = 1 + \lambda_{i,\text{source}} + \lambda_{i,\text{sink}}$

dependence relation changes $\lambda_{0,i}$ when it should not.

The difficulty arises from the fact that

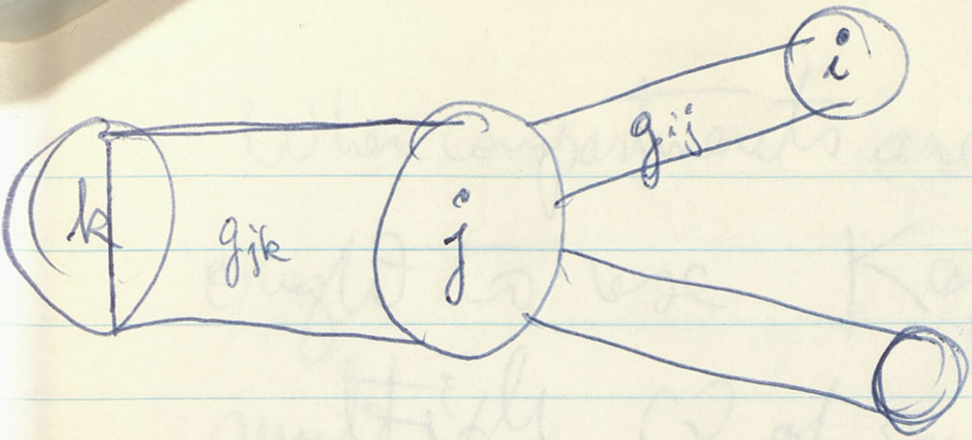
$\lambda_{0,i}$ multiplies q_i and $\therefore$

$$\lambda_{0,i} = 1 + \Sigma + J$$

quite independent of size

where Σ & J are per unit area of membrane

However, $\lambda_{i,\text{source}}$ multiplies q_{source}



Suppose $c_i = \frac{1}{2} c_j$

$g_{ij} = \frac{1}{2} g_{jk}$

$$\lambda_{i,j} = \frac{g_{ij}}{c_j} = \frac{1}{2} \lambda_{jk} = \frac{1}{2} \lambda_{kj} = \frac{1}{2} \lambda_{j,i}$$

$$\lambda_{j,i} = \frac{g_{ij}}{c_i} = \lambda_{jk} = \lambda_{kj}$$

$$\lambda_{ii} = \lambda_{0i} + \sum_{j \neq i} \lambda_{ji}$$

$$= 1 + \varepsilon + J + \sum_{j \neq i}' \lambda_{ji}$$

all of which should be unaffected by size of i

Note

When compartments are unequal ought to use Koppos to multiply C_j of smaller compartments.

where C_j is standard

Suppose $C_i = C_j / f$ say $f = 2$

then $\lambda_{i,source} = \mathcal{E}/f$

$\lambda_{i,sink} = g/f$

$\lambda_{i,j} = \lambda_{j,i}/f$

But then $K_i = f$

and also $\lambda_{0i} = 1 + f * \lambda_{isource} + f * \lambda_{isink}$

or for 731.100 series $\lambda_{11,1} = 1 + f * \lambda_{1,8} + f * \lambda_{1,9}$

etc

Koppos come between 26-1 & 26-2

Use of drum with key punch

skipping, duplicating & alphabetic punching.

fields indicated on drum card by row of (+) for numeric
(except for first col. in field) row of (A) for alphanumeric duplication or for alphabetic punching

(–) in first col. of field produces skip of field.

(0) - - - - - - - - - produces duplication

A single (0) duplicates a single col. field.

(0+1) = / is needed to duplicate a field if the first number of the field is blank.

0AAAA–+++

Does not automatically duplicate and skip if A field is empty.

BERMAN - WEISS
NIH - OMR

(1)

PAGE ___ OF ___

		PROBLEM NUMBER AND MODEL IDENT. (decimal)		DATE	NAME OR OTHER IDENTIFICATION	PROBLEM NUMBER	
1	2 → 10	13 → 20	22 → 25	27 → 37	40 → 72	73 → 76	80
1	DATA DECK	732.300	9B21	11.15.63	RALL PHR-MODEL-1	7323	1

PROBLEM NUMBER (decimal)	NUMBER OF COMPARTMENTS (integer)		NUMBER OF ITERATIONS (integer)			PROBLEM NUMBER	
2 → 9	19	20	29	30		73 → 76	80
732.301	1	3					2

		P_1	E		CONMIN	PROBLEM NUMBER	
5 → 7	21 → 30	31 → 40	41 → 50		61 → 70	73 → 76	80
		.01	.98		.98		3

ERROR MATRIX	PARTIALS MATRIX	PLOT	A-MATRIX BEFORE INVERSION	INTERMEDIATE RESULTS		0 = PROGRAM CHOOSES 1 or 2 1 = LINEAR DIF. EQUATION 2 = EXPONENTIAL SOLUTION 3 and up = SPECIAL SYSTEMS (integer)						PROBLEM NUMBER	
2	3	4	5	6	10 → 18	49	50	55	60	65	70	73 → 76	80
		4			OPTIONS								4

PHS-4583-1
9-63

WORK SHEET FOR COMPUTER PROGRAM 9B

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(2)

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DATA

	COMPARTMENT NUMBER (decimal)	TIME (decimal)	OBSERVED VALUE (decimal)	WEIGHT (decimal)	CODE FOR WT. (integer)	θ (decimal)	PROBLEM NUMBER
	2 → 5	12 → 25	27 → 40	42 → 55	57	59 → 72	73 → 76
	1.		~~1.~~ 0.5				
	1.	.1					
	1.	.2					
	2.						
	↓	.1					
		.2					
	3.						
	↓	.1					
		.2					
	4.						
	↓	.1					
		.2					
	11.						
	↓	.1					
15		.2					
	13.						
+5	200.	.05		4.			
	126.	1.	1.				
	1.	.3					
	200.	.1		9.			
	2.	.3					
	200.	.1		9.			
	3.	.3					
	200.	.1		9.			
	4.	.3					
	200.	.1		9.			
	11.	.3					
+50	200.	.1		9.			
	13.	.25					
+20	200.	.05		19.			
	126.						
	1.						
	200.	.5		10.			

PHS-4583-2
9-63

WORK SHEET FOR COMPUTER PROGRAM 9B

BERMAN - WEISS
NIH - OMR

PAGE ___ OF ___

DATA

	COMPARTMENT NUMBER (decimal)	TIME (decimal)	OBSERVED VALUE (decimal)	WEIGHT (decimal)	CODE FOR WT. (integer)	θ (decimal)	PROBLEM NUMBER
	2 → 5	12 → 25	27 → 40	42 → 55	57	59 → 72	73 → 76
	2.						
	200.	.5		10.			
	3.						
	200.	.5		10.			
	4.						
	200.	.5		10.			
	11.						
+55	200.	.5		10.			
	13.						
+26	200.	.2		25.			
	126.	1.	1.				
	1.	5.5					
	200.	.5		9.			
	2.	5.5					
	200.	.5		9.			
	3.	5.5					
	200.	.5		9.			
	4.	5.5					
	200.	.5		9.			
	11.	5.5					
+50	200.	.5		9.			
	13	5.2					
+25	200.	.2		24.			

```
    *T
  15
   5
  50
  20
  55
  26
  50
  25
 246*T
```

INITIAL CONDITIONS

COMPARTMENT NUMBER (integer)		INITIAL CONDITION FOR COMPARTMENT (decimal)	COMPARTMENT SIZE (decimal)	STEADY STATE INFLOW RATE (decimal)	PROBLEM NUMBER	ENTER "1"
4	5	12 → 25	42 → 55	56 → 70	73 → 76	78
2	6					0
	8	1000.				1
1	0	1000.				1
2	6					1

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PAGE ___ OF ___

LAMBDAS

Transfer rates for Compartments

COMPARTMENT NUMBER (Integer) Into	From	INITIAL ESTIMATES (Fixed and Independently Variable λ's (decimal)	MINIMUM LIMIT (independent λ only) (decimal)	MAXIMUM LIMIT (independent λ only) (decimal)	Q DEPEND. (integer)			Enter "1" (dependent λ only) (integer)	STAT. INFO. (dec.)	PROBLEM NUMBER	ENTER "3"
4 5	9 10	12 → 25	27 → 40	42 → 55	57	58	59	60	62→72	73→76	78
2 6											2
1	10										
2	1	10.									
3	2	10.									
4	3	10.									
	4	2.									
11	12	4.									
12	11	4.									
12	13	4.									
13	12	4.									
	11	1.									
	12	1.									
	13	1.									
11	8	.005					1				
12	8	.005	become Q_8 =1000.				2				
13	8	.005					3				
8	11	.005					1				
8	12	.005	goofed				2				
8	13	.005					3				
9	11	.5					4				
9	12	.5					4				
9	13	.5					4				
	10							1			
26											3

DEPENDENT RELATIONS

$$P_j = \sum A_i P_i + C$$

DEPENDENT PARAMETER COMPARTMENT NUMBER (integer)				DEPENDED-ON PARAMETER COMPARTMENT NUMBER (0, 0 for a constant) (integer)				COEFFICIENT OF DEPENDED-ON PARAMETER OR A CONSTANT (decimal)	PROBLEM NUMBER	ENTER "5"
Into (for λ, σ, κ)		From (for λ, σ)		Into (for λ, σ, κ)		From (for λ, σ)				
4	5	9	10	19	20	24	25	27 → 40	73 → 76	78
2	6									4
		1	0		1	1	0	-1.		5
2	6									5

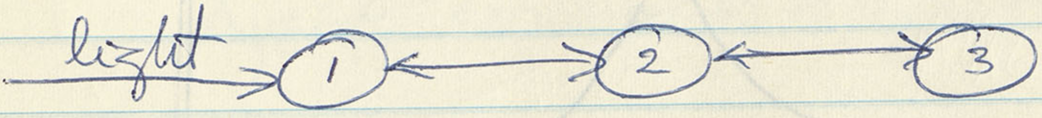
INITIAL CONDITIONS CHANGES							
COMPARTMENT (integer)		AT TIME CHANGE 1 (decimal)	AT TIME CHANGE 2 (decimal)	AT TIME CHANGE 3 (decimal)	AT TIME CHANGE 4 (decimal)	PROBLEM NUMBER	ENTER "7"
4	5	7 → 20	21 → 35	36 → 50	51 → 65	73 → 76	80
	8		1000.				
1	0		1000.				
2	6						7
2	6						7

SUBSCRIPTS OF PARAMETERS X_{ij} WHOSE VALUES ARE TO BE CHANGED				CHANGES IN PARAMETERS* $X'_{ij} = AX_{ij} + B$		PROBLEM NUMBER	ENTER "10" ZERO TIME "11" FIRST CHANGE "12" SECOND CHANGE "13" THIRD CHANGE "14" FOURTH CHANGE	
COMPARTMENT NUMBER (integer)				A (decimal)	B (decimal)			
Into		From						
4	5	9	10	12 → 25	26 → 40	73 → 76	79	80
	1	1	0		.02		1	0
2	6						1	0
	1	1	0				1	1
2	6						1	1
	1	1	0		.01		1	2
2	6						1	2
	1	1	0				1	3
2	6						1	3

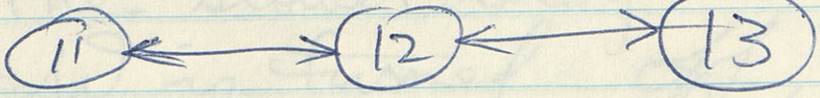
* A "26" termination in columns 4 and 5 must be entered for changes at zero time and each additional time change whether or not changes in parameters are entered

11/15/63

New model for photoreceptor kinetics which embodies some of the spatio-temporal G_E notions of my dendritic tree model.

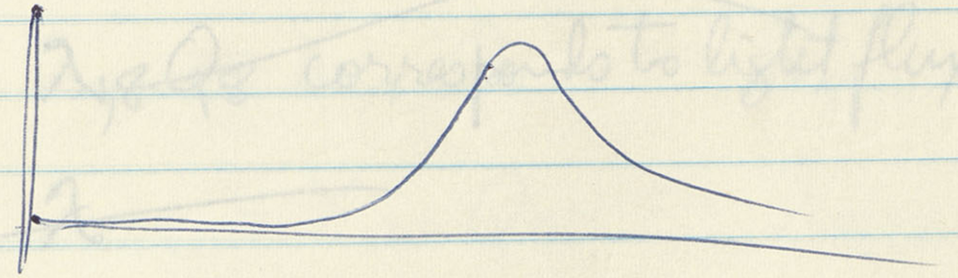


This chain can represent light absorption followed by [illegible] photochemical kinetics, and or diffusion of resulting pseudo transmitter substance which alters the G_E of corresponding membrane segments similar to dendritic cylinder



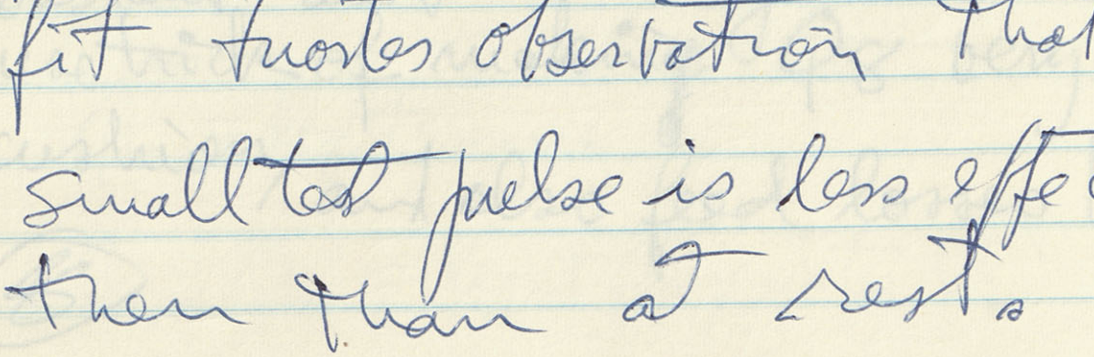
~~brief pulse will affect mainly ① & hence mainly only ⑪ briefly~~

Contrary to limitations of linear systems (delay & slope) as emphasized by Hodgkin & Hagins, this can have a delayed steep rise, just as my dendritic sequence (D – C – B – A)



which will be here produced by the spread from ① to ③.

Also the slower decay in ① ② ③ after light is turned off, would fit Fuortes observation that a small test pulse is less effective then than at rest.



Set up first test as follows

~~$Q_{10} = 1.0$ $\lambda_{10,10} = 0$~~

~~$\lambda_{1,8} Q_8$ corresponds to light flux into ①~~

~~λ~~

Note: because $\lambda_{11,8}$

$\lambda_{12,8}$

$\lambda_{13,8}$

must be Q dependent, I cannot use dependence relations to maintain Q8 constant as I usually do. Therefore, use trick of making Q8 very large cushion, and also feed losses back into

⑥

Thus we will make

$$Q_8 = \overset{1000}{1000}$$

$$\lambda_{11,8} = \gamma_{11,8} Q_1 = \lambda_{8,11}$$

$$\lambda_{12,8} = \gamma_{12,8} Q_2 = \lambda_{8,12}$$

$$\lambda_{13,8} = \gamma_{13,8} Q_3 = \lambda_{8,13}$$

$$\lambda_{0,11} = \lambda_{0,12} = \lambda_{0,13} = 1.0$$

$$\boxed{\lambda_{11,11} = \lambda_{0,11} + \lambda_{8,11} + \lambda_{12,11}}$$

$$\lambda_{11,12} = \lambda_{12,11} = \lambda_{ij} = \text{say } 4.$$

Q_{10} = light source

$\lambda_{1,10} Q_{10}$ = light flux into ① probably need to add an inhibition or accomodation, could ~~make~~ start by making this follow cf. ④, say.

for a start could be made more complicated later.

i.e. $\lambda_{9,11} = \gamma_{9,11} Q_4$

$\lambda_{9,12} = \gamma_{9,12} Q_4$

$\lambda_{9,13} = \gamma_{9,13} Q_4$

Ⓐ brief ~~square~~ step. $T_1 - T_0 \approx 0.2$ $T_2 - T_1 = 0.8$

Ⓑ longer ~~square~~ step. $T_3 - T_2 = 5$, $T_4 - T_3 = 2$

∴ in ⑬ want ~~five~~ four .05 & then 20 .05

then ~~ten .5~~ 20 .25, followed by 20 .25

total 64 + 4 = 68

in ①, ②, ③, ④ ~~two .1~~, ten .1

⑪, [illegible]

$68 + \frac{4}{2}(68) = 3(68) \overset{2}{=} 204$

Operating Suggestions

① main switch, ② Release button, to test readiness.

For master information to be punched in, keep automatic skip switch off.

it is unnecessary to disengage drum with program control lever.

Temporary stop of operation: switch off automatic feed before releasing card.

For Drum Cards

(12) + (1) = (A) to designate alphanumeric field

(12) = (+) to designate numeric field.

0 automatic duplicate numeric

(0) + (1) = (/) automatic duplicate alphanumeric

(11) = (-) = automatic Skip space and field immediately adjacent.

(2) is for left zero print, i.e. zero to left to fill field.

(3) is for print suppression

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